DOCUMENT RESUME

ED 081 618 SE 016 656

TITLE	The American Environment: A Home Study Course.
INSTITUTION	Soil Conservation Service (DOA), Washington, D.C.
PUB DATE	Apr 71
NOTE	183p.; Revised January, 1973
EDRS PRICE	MF-$0.65 HC-$6.58
DESCRIPTORS	Adult Education; *Course Content; Curriculum Guides; Environment; *Environmental Education; *Independent Study; Instructional Materials; Natural Resources; *Professional Continuing Education; *Units of Study (Subject Fields)

ABSTRACT

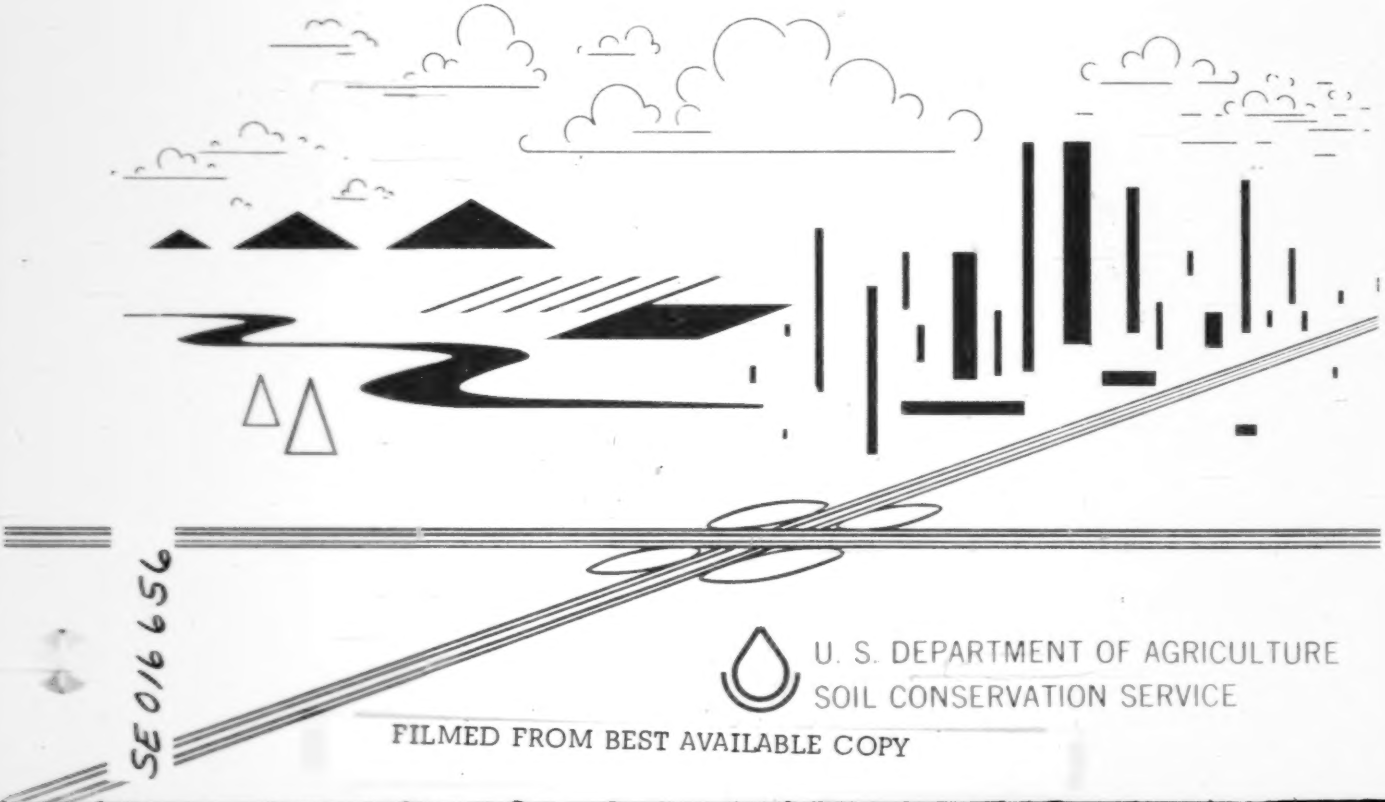
Prepared for employees of the Soil Conservation Service, U. S. Department of Agriculture, to assist them in increasing their knowledge and understanding of the environment, this syllabus may also serve as a resource and reference guide for environmental studies or for purposes of curriculum development. The 16 unit course consists of reading assignments, activity assignments, subject information summaries, support materials, and response sheets. Topics are: The "Original" American Situation; Changes in America Since AD 1500; Basic Biological Concepts; Basic Ecological Concepts; The Atmosphere; Soils; Freshwater and Its Pollution; Oceans and Estuaries; Natural Areas and Their Use; Wildlife; Population of Human Beings; Solid Waste Problems; Persistent Chemicals in the Environment; Radioactive Fallout; Living Space and Recreation; and The Law and the Environment. (BL)

U S DEPARTMENT OF HEALTH
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

ED 081618

the
american
environment

A HOME STUDY COURSE



U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SE 016 656

FILMED FROM BEST AVAILABLE COPY

THE AMERICAN ENVIRONMENT

A Home Study Course

SOIL CONSERVATION SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

Prepared for employees of the Soil
Conservation Service to assist them
in increasing their knowledge and
understanding of the environment.

Issued April 1971
Revised January, 1973

HOW TO USE AND DEVELOP
THIS BOOK

All the materials in this book have been punched for a three-ring binder. In doing this, we had in mind the following ideas:

1. Materials and lessons can be taken out and put back in easily.

2. New material you collect, can be punched and inserted easily. If you keep on collecting notes, quotations, excerpts, booklets, pamphlets, book reviews, etc. -- you will find that this book will grow -- as your knowledge grows. It will become your environmental reference.

3. From time to time new materials are being and will be issued by the SCS. When you get your copy, this book is a mighty good place to file it, after study.

The Soil Conservation Service occupies a major position in the United States as an environmental agency. The work we do, in cooperation with conservation districts and other agencies, has a tremendous effect on the lands and waters of our country.

This being so, it is of key importance that all of our technical people be as up-to-date as possible in the many environmental sciences. It is urgent that we undertake our work on the most enlightened, scientifically sound basis possible.

This home study course is designed to help technical people increase their knowledge and improve their understanding of the environment. Anyone taking it will need to plan on more reading after finishing it, or for that matter even during the course. The world does not stand still. It is my hope that among other things this course will act as a stimulant to further study.

Before Starting the Course - - -

1. You will be expected to read and study on your own time, work assigned problems, answer questions, and return this paper work to your instructor for review. A student response sheet is provided at the end of each unit. This should be torn out and used as the transmittal sheet and first page for responding to the assignment.

2. We estimate that it will take you approximately 160 hours to complete the course. This means that you will need to schedule up to 10 hours of your own time each month for 16 months, if you are to complete the course at the suggested rate of at least one unit per month. You may, of course, complete the lessons more rapidly than this if you are able to.

   It is important that you be sure that your work and travel commitments, as well as social commitments, enable you to schedule 10 hours a month for this course. If you really don't have the time, you will be well advised not to start. A simple form for completing a study plan is provided. Please complete two copies of this form; sending one to your instructor and keeping one for your own guidance. If for any reason you fall behind, a new schedule should be prepared and concurred in by the instructor.

Books You Will Need

1. Some of the information you will need is in this course manual. In addition, however, you will need the following:

   Fundamentals of Ecology, by Eugene P. Odum,
   W. B. Saunders Co., Philadelphia, 3rd ed., 1971.
   574 pp.

   Environment and Man, by Richard W. Wagner,
   W. W. Norton and Co., Inc., New York, 1971.
   491 pp.

   Population, Environment, and People, edited by
   Noel Hinrichs, McGraw-Hill, New York, 1971.
   227 pp.

   Air Pollution Primer, by Rena Corman. National Tuberculosis
   and Respiratory Disease Association. New York, 104 pp.

   The Oxygen Cycle, by Preston Cloud and Aharon Giber.
   Scientific American offprint. N.Y. 1970. 14 pp.

   Atoms, Nature, and Man, by Neal O. Hines. U.S. Atomic
   Energy Comm., Oak Ridge, Tenn. 1966. 57 pp.

   To Live on Earth by Sterling Brubaker. Published for
   Resources for the Future by Johns Hopkins Press,
   Baltimore, 1972. Mentor Paperback.

2. A flora of your area will help you identify the plants you find. Go to your library and look at pictures in the largest books. Ask associates or knowledgeable friends to help you. For animals you may need books on mammals, birds, reptiles, amphibians, insects, etc. Use the library and ask associates. All this means you may need to collect specimens of the plants or animals you cannot identify-- to show, and to compare with pictures.

3. Use the list of books included below as sources where you may be able to find information needed in developing your paper and reports. If you are near a library of any size, check what is available on any subjects you are studying. If you can afford to do so, by all means accumulate a small reference library of your own.

Supplies You Will Find Handy

A hand lens.
A pair of binoculars.
Some small containers for insects such as jars, bottles, etc.
Some small paper sacks or "baggies."
A field notebook for recording observations.
An inquiring mind.

Additional Recommended Reading

Books deserving special attention:

Bartelli, L. J., Klingebiel, A. A., Baird, J. V., and Heddleson, M. R., 1966. Soil Surveys and Land Use Planning. Soil Science Society of America and American Society of Agronomy, Madison, Wisconsin, 196 pp.

Boughey, Arthur S., 1971. Fundamental Ecology. Intext Educational Publishers, San Francisco. 22 pp. Paperback.

Boughey, Arthur S., 1971. Man and the Environment. An introduction to human ecology and evolution. MacMillan, New York. 472 pp. Paperback $6.95.

Carvell, Fred, and Max Tadlock, 1971. It's Not Too Late. Glencoe Press, Beverly Hills, Calif. 312 pp. Paperback.

Council on Environmental Quality, 1970. Environmental Quality. First annual report of the Council, U.S. Gov. Printing Office, 326 pp. Second annual report, same publisher, 360 pp. ($2.00) 1971; and following annual reports.

Dasmann, Raymond F., 1968. Environmental Conservation. John Wiley and Sons, New York. 2nd ed. 375 pp. Paperback.

Eiseley, Loren, 1957. The Immense Journey. Vintage Books, New York, 210 pp. Paperback $1.45. Pleasant, scientifically sound reading on man and his development and environment.

Handler, Philip, ed., 1970. Biology and the Future of Man. Oxford University Press, New York. 936 pp. ($12.50) An exhaustive review by a large panel of scientists of our state of knowledge in the biological field. Paperback $4.95.

Matthiessen, Peter, 1959. Wildlife in America. Viking, New York, 304 pp. Paperback $1.95.

Schwartz, William, ed., 1969. Voices for the Wilderness. Sierra Club-Ballantine, N.Y., 366 pp. Paperback $1.25. A series of selected readings on the subject.

Scientific American, 1970. Entire issue on the biosphere. Sept. 1970. 266 pp. $1.00. A group of articles written by scientists, including the various cycles (oxygen, carbon, nitrogen, etc.).

Shepard, Paul, and Daniel McKinley, 1969. The Subversive Science. Subtitle: Essays Toward an Ecology of Man. Houghton Mifflin, Boston, Mass., 453 pp. Paperback $5.95. Highly competent essays; thought-provoking.

The Editors of Fortune, 1970. The Environment. Harper & Row, New York and Evanston, 220 pp. Paperback $1.25. A summary prepared by the editors of Fortune magazine. A useful introduction to the subject.

Instructions: Fill out two of these forms by using a carbon paper. You and your supervisor should both sign the plan. Send one copy to your instructor; keep the other and follow it. In the top row of boxes place the dates when you plan to complete each unit. Place an "X" or check mark opposite each unit under the proper date.

STUDY PLAN

Name: ______________________________

Headquarters: ______________________________

Unit No.	Subject Fill in Dates →																	Remarks
1	"Original" Situation																	
2	Changes in America since AD 1500																	
3	Basic Biological Concepts																	
4	Basic Ecological Concepts																	
5	The Atmosphere																	
6	Soils																	
7	Freshwater																	
8	Oceans and Estuaries																	
9	Natural Areas and Their Use																	
10	Wildlife																	

______________________________ Employee's Signature

______________________________ Supervisor's Signature

Study Plan continued

Unit No.	Subject Fill in Dates →																	Remarks
11	Population of Human Beings																	
12	Solid Waste Problems																	
13	Persistent Chemicals in the Environment																	
14	Radioactive Fallout																	
15	Living Space and Recreation																	
16	The Law and the Environment																	

Instructions: Fill out two of these forms by using a carbon paper. You and your supervisor should both sign the plan. Send one copy to your instructor; keep the other and follow it. In the top row of boxes place the dates when you plan to complete each unit. Place an "X" or check mark opposite each unit under the proper date.

S T U D Y   P L A N

Name: ____________________

Headquarters: ____________________

Unit No.	Subject Fill in Dates →																	Remarks
1	"Original" Situation																	
2	Changes in America since AD 1500																	
3	Basic Biological Concepts																	
4	Basic Ecological Concepts																	
5	The Atmosphere																	
6	Soils																	
7	Freshwater																	
8	Oceans and Estuaries																	
9	Natural Areas and Their Use																	
10	Wildlife																	

____
Employee's Signature

____
Supervisor's Signature.

Study Plan continued

Unit No.	Subject Fill in Dates →																	Remarks
11	Population of Human Beings																	
12	Solid Waste Problems																	
13	Persistent Chemicals in the Environment																	
14	Radioactive Fallout																	
15	Living Space and Recreation																	
16	The Law and the Environment																	

THE ENVIRONMENT

Unit 1 Page 1

The "original" situation. The flora and fauna at about AD 1500. The Indian population and the effects of the Indians and their ancestors on the natural resources.

Unit 2 Page 3

Changes in American since AD 1500. The conspicuous changes, including clearing, settlement, irrigation, drainage, changes in human population and wildlife populations, pollution, etc. The less conspicuous changes including radioactivity, atmospheric composition, etc., changes in the American attitude about the environment.

Unit 3 Page 7

Basic biological concepts, including photosynthesis; chemosynthesis; respiration; origin of the earth's atmosphere, origin of living things, evolution.

Unit 4 Page 15

Basic ecological concepts, including succession, food chains, biogeochemical cycles (H, C, O, water, etc.), biological communities, territory, habitat, niches, resiliance (homeostasis), etc.

Unit 5 Page 26

The atmosphere, its composition, origin, changes in oxygen and carbon dioxide and their possible effects; additions of particles (smog, etc.) and other materials, such as radioactive particles and DDT; relation of atmospheric changes to human beings.

Unit 6 Page 39

Soils, with special reference to soil organisms and their functions; degradation of soils including erosion and its effects, salinity, alkalinity; improvement of soils for farming, arable lands.

Unit 7 Page 53

Freshwater; water quantities and quality in the U. S.; pollution by sediment, sewage, industrial wastes, agricultural wastes, eutrophication, thermal pollution, impact of recreation uses.

Unit 8 Page 69

Oceans and estuaries; values of estuaries; fisheries in relation to estuaries and the oceans; status of fisheries; oil pollution; ocean dumping; action of the ocean in relation to biogeochemical cycles, climate, temerature balance; desalination of sea and brackish water.

Unit 9 Page 71

Natural areas and their use. Parks, refuges, wilderness areas, scientific preserves; problems in the management of natural areas, programs underway.

Unit 10 Page 80

Wildlife. "Original" populations of various key species; exterminated species, causes underlying extermination; rare and vanishing species; prospects for saving threatened forms.

Unit 11 Page 88

Population of human beings; development and trends in the U. S. and in the rest of the world; hunger problems, dietary problems; developing technology accompanying human increases.

Unit 12 Page 94

Solid waste problems; kinds, including sewage, garbage, paper, metals, glass, trash, street sweepings; amounts; sanitary landfills; recycling; trends.

Unit 13 Page 126

Persistent chemicals in the environment; insecticides, weedicides, fungicides, rodenticides; other sprays; detergents, lead, mercury and other pollutants; concentration by organisms, unexpected effects, technological trends.

Unit 14 Page 140

Radioactive fallout in relation to human beings and the environment; radioactive wastes from nuclear power plants, and their disposal.

Unit 15 Page 142

Living space and recreation; metropolitan areas and their problems resulting from concentration and crowding of human beings. Rural living, open spaces, recreation needs and potentials.

Unit 16 Page 144

The law and the environment; role of government; legal precedents in conservation law; Council on Environmental Quality and its effects; the role of the citizen.

Digest and Summary
of
Problems and Final Paper

Unit 1

Find out all you can about the "original" flora and fauna of the area where you live. What tribe or tribes of Indians were there? Prepare a brief report.

Unit 2

What changes have taken place in your area since about 1500 AD? Describe briefly, bringing the story up-to-date. Be sure to include all important changes in vegetation, fauna, and earlier populations of Indians. In your judgment, what is the future trend? Turn this in with Unit No. 3.

Unit 3

(Turn in report begun with Unit 2.)

Unit 4

Determine the ecological succession for your area. See detailed discussion for Unit 4 attached. Turn this in with Unit 5.

Unit 5

(Turn in report begun with Unit 4.)

Unit 6

Check the macro-organisms in humus. See detailed discussion for Unit 6, attached. Report.

Unit 7

Find out about the domestic water supply system for you area, also the sewage disposal system. When were they set up and by whom? How effective is each now? For the immediate future (5-10 years)? Turn this report in with Unit 8.

Unit 8

(Turn in report begun with Unit 7.)

Unit 9

Locate and describe the nearest natural area in your vicinity. Why and how was it set up, and by whom? How is it administered?

Turn in report with Unit 10.

Unit 10

(Turn in report begun with Unit 9.)

Unit 11

Send in a subject on which you would like to prepare a paper, with a brief outline setting forth major points you might treat. (Avoid subjects on which you are already well informed.)

Unit 12

Report on how solid waste (excluding human sewage) is disposed of in your area.

Unit 13-16

Develop your "term paper" and hand in with Unit 16.

UNIT NO. 1

THE "ORIGINAL" AMERICA

Unit No. 1

The "Original" America

Reading assignment: Odum, pp. 378-403

At your local library, check with the librarian to find county histories, local books on trees, grasses, wild flowers, birds, mammals, and the like. Be sure to obtain correct citations to material you use (name of author, title, publisher, date, number of pages).

Assignment:

Find out all you can about the "original" population of Indians, the flora, and the fauna of the area where you live.

1. What tribe or tribes of Indians were there? How many Indians? What did they live on? Did they migrate or did they have settlements? What effects did they have on the vegetation or fauna? Were the effects great or minimal? How do you know this?

2. Depending on the kind of vegetation characteristic of your area, what were the dominant species of trees, shrubs, or grasses? Determine, if you can, the approximate percentage composition of the dominants.

3. What mammals, birds, reptiles, amphibians, and fish were present? List at least the larger and more common ones.

4. Prepare a report and turn it in.

(Note: In preparing this report, have a look at Unit 2, for which you may wish to refer to the same local sources.)

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name: ______________________________

Address: ____________________________

____

Working Title: _______________________

Unit No. & Title: _____________________

____

Date Submitted: ______________________

Hours Spent on this lesson: __________

(Block below for instructor use)

Date Received: _______________

Date Returned: _______________

Comments:

____

(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 2

CHANGES SINCE 1500 A. D.

Unit No. 2

Changes since 1500 A.D.

Reading assignment: Odum, pp. 408-431, 432-450, Changes in the United States.

Wagner: Chapters 2, 15

Use also local histories, floras, and faunas as noted in Unit 1, together with books on pollution.

Assignment:

1. Determine and list the changes that have taken place in your area, beginning with the earliest date you can find of intrusion by white men. Consider exploration, trapping, hunting, clearing, cultivation, soil amendments, drainage, irrigation, grazing, any strip-mining, erosion, pollution of waters by various substances, smog, urban development, increases or decreases in Indian and white population, use of pesticides, radioactivity. Also consider introduced plants and animals and their effects (weeds, insects, birds, game animals, fish).
2. Under each kind of change indicate briefly the approximate magnitude of the change.
3. In your judgment, what trends are indicated in your area, for the reasonably near future?
4. Turn in this report with your assignment for Unit 3.

Unit No. 2

Changes in the United States
(from about 1500 to 1970)

The large-scale, obvious changes

A. Changes in the landscape from "primeval" or "original" conditions:

1. The clearing of land
2. The plowing of land and planting of crops
3. Pollution of streams, lakes, rivers by erosion sediment
4. The draining of wet lands
5. The irrigation of dry lands
6. The grazing of rangelands by livestock
7. Strip-mining, mine tailings, slag heaps
8. Damming of streams and rivers
9. Growth of metropolitan areas, with associated airports, superhighways, and other facilities
10. Covering of large areas by impervious materials such as asphalt, concrete, and tar
11. Development of smog.

B. Reduction of Indian populations, extermination of some tribes, and placement of remnants on reservations.

C. Changes in populations of existing animals:

1. Reduction, and in some cases extermination, of dangerous animals (bears, lions, snakes)
2. Reduction in numbers of certain big-game animals (buffalo, moose, antelope, elk)
3. Extermination of 48 species of wildlife, and reduction of populations of 78 others to the rare or endangered category
4. Increases in populations of certain birds (bobwhite, quail), and mammals (white-tailed deer)
5. Changes in invertebrate populations have been from slight to cataclysmic, but most forms not studied sufficiently to know what has happened to them. (Includes a wide variety of animals, such as crabs, clams, oysters, crayfish, spiders, insects, snails, earthworms, etc.).

D. Introduction of plants and animals, including:

1. Common weeds, generally from Europe (dandelions, ragweed, several thistles, plantains, morning-glory, St. Johnswort, halogeton)
2. Insects (Japanese beetle, cotton boll weevil, bees)
3. Virus, bacterial, and fungus diseases (Dutch elm disease, chestnut blight)
4. Trees and shrubs (tree-of-heaven, chinaberry, Scotch broom)

5. Game and song birds (ringneck pheasant, Hungarian partridge, English sparrow, pigeons, starling)
6. Game animals (European boar, various Asiatic deer, zebra)
7. Other animals (nutria, mongoose, rats)
8. Fish (generally moving native species from one place to another; introductions from other countries are rare)

E. Population of human beings--increases in both numbers of people, their concentration in metropolitan areas, their needs, their waste products.

The more subtle changes

1. Former inter-relationships with native plants and animals, some of which are now gone, and many of which are drastically reduced in numbers
2. Radioactive fallout
3. Pesticide fallout and relation to plants, animals, and man
4. Light over cities
5. Particulate matter in the atmosphere
6. Chemical pollution of waters, including organic compounds, detergents, lead, mercury, arsenic
7. Use of fertilizers
8. Noise (planes, cars, effects on animals and man)
9. Change in carbon dioxide content of the atmosphere. Fossil fuel combustion
10. Change in ozone in outer stratosphere
11. Nitrous oxide, lead and pesticides in atmosphere
12. Thermal pollution of waters
13. Snowmobiles and their effects on vegetation and wildlife.

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name: ______________________________

Address: ___________________________

____

Working Title: _____________________

Unit No. & Title: ___________________

____

Date Submitted: ____________________

Hours Spent on this lesson: ________

(Block below for instructor use)

Date Received: ______________

Date Returned: ______________

Comments:

____

(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 3

BASIC BIOLOGICAL CONCEPTS

Unit No. 3

Basic Biological Concepts

Reading Assignment

The Oxygen Cycle, by Cloud and Gibor.

Some Basic Biological Processes, prepared by W. R. Van Dersal.

Production and Decomposition in Nature, pp. 24-33 of Odum's Ecology.

Assignment

1. Turn in report begun with Unit 2.
2. Begin (if you have not already done so) clipping newspapers and magazine accounts of any sort dealing with the environment. Organize these by subject-matter, in large envelopes, or pasted into sheets in 3-ring binders.

   Continue this clipping collection throughout the course.

Unit No. 3

Some Basic Biological Processes

All green plants and certain bacteria are able to manufacture sugar from water and carbon dioxide. Animals cannot do this; but even so, animals must have sugar as a basic food in order to live or survive. This is why we say that animal life and human beings depend on plants.

The process that goes on in green plants, everywhere, on land and in ponds, or streams, or the ocean, is called photosynthesis. It works like this:

$$\text{Water + carbon dioxide} \xrightarrow{\text{produces}} \text{sugar + oxygen.}$$

This is the synthesis part of the word photo-synthesis. Synthesis means to build or put together. Water, added chemically to carbon dioxide produces sugar and oxygen. But this synthesis or adding together can only go on in the presence of sunlight, and only in plants containing green color, or chlorophyll. If we show the process correctly then,

$$\text{Water + carbon dioxide} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \text{sugar + oxygen}$$

This appears pretty simple. But scientists are still not entirely sure how plants can do this. We humans so far have not been able to do it ourselves. We know what the plant starts with; we know sunlight provides the energy; we know chlorophyll helps it happen; we know some of the intermediate products; and we know what the end products are. If we could do it, we could manufacture our own sugar from water and carbon dioxide. As it is, however, we must still depend on green plants to do it. We eat them for food, or we eat animals that feed on plants.

Notice one other thing. Oxygen is a product of photosynthesis. We have to have oxygen also, and green plants keep the atmosphere supply of oxygen replenished. There is no other source of oxygen of any importance. If anything happened to retard or arrest photosynthesis, the world would soon be in trouble. Gradually, should this happen, the atmospheric oxygen would be used up by animal life. There would be no replenishment of oxygen, and animal life would come to an end when the oxygen supply got low enough.

Thus, photosynthesis is important to us in two ways. It provides us with sugar--the basis for our proteins and protoplasm. And, it keeps replenishing the oxygen in our atmosphere. We must have this oxygen to survive.

(As shown here, and in many texts, the first product of photosynthesis is said to be a simple sugar. Actually the specific carbohydrate involved cannot be designated on the basis of available information. Thus, a more correct chemical equation would be:

$$6CO_2 + 6H_2O \longrightarrow (CH_2O)_n + 6O_2$$

The presence of sunlight is required for the first part of the process, but photosynthesis is not a single photochemical reaction. A thermochemical reaction, not affected by light, and apparently requiring darkness, follows the photochemical one.)

Once a simple sugar has been made by a green plant (and oxygen given off in the process), the plant goes on to build a series of other compounds known as carbohydrates. These carbohydrates consist of many kinds of sugars--such as glucose, the first product of photosynthesis; sucrose or table sugar, starch, and cellulose (of which most paper is made).

Carbohydrates are chemical compounds that contain carbon, hydrogen, and oxygen. The hydrogen and oxygen are present in the same proportion as they are in water (thus, hydrates). Most people know that water is H_2O, which means that a single molecule of water contains two atoms of hydrogen for each atom of oxygen.

Green plants don't have to have sunlight to build these later carbohydrates; they can do it in the dark. And, they don't need chlorophyll either, except for the first carbohydrate, basic to all the rest. Even a fungus such as a mushroom entirely lacking chlorophyll, can build carbohydrates if it can get the simple sugar to start with by decomposing dead plants or animals.

Animals can build carbohydrates also, as long as they can get glucose or a similar carbohydrate as a starter. They form sugars and starches that are only slightly different from those formed by plants. Animals can also manufacture fats; plants can likewise build oils, fats, and waxes.

Some animals proceed to develop chitin--a hard, horny material that makes up the hard shell-like parts of insects. Plants develop lignin--the hard material of wood. Both chitin and lignin are carbohydrates--with the same ratio of 1 part of hydrogen to 2 parts of oxygen.

By adding nitrogen, phosphorus, calcium, magnesium, sulfur, and some other chemicals to the carbohydrate materials, plants as well as animals can manufacture proteins. This process is chemically highly complex. It results in giant molecules that in turn are built into protoplasm, the living substance of the plant or animal. We do not know how this is done either, although we know a great deal about the building blocks, many of the intermediate steps, and the end products.

Proteins, (and thus protoplasm) always contain nitrogen whatever other elements they may have. They occur only inside the living cell, and under natural conditions they are never found outside it unless secreted or given off by the living cells themselves.

Most plants cannot take nitrogen from the air, although there is plenty of it in the atmosphere. They must get it from the soil in the form of nitrates. Nitrates are made available to the roots of higher plants by the activities of the micro-organisms that live in the soil. Some of these microbes produce nitrates when they decompose dead animals and plants. If they did not do this, higher plants could not get nitrogen for protein and protoplasm building. Thus, decay is a very important process indeed.

Given the elements we have noted so far, plus a few others for some special products of both plants and animals, living organisms develop all the host of chemical materials necessary for life and growth.

Respiration

Everyone learns in school that we humans must have oxygen to breathe. Our lives depend upon it. It is also true that almost all animals and plants depend upon oxygen for their existence.

This comes about because plants and animals, including humans, get their energy from a chemical process known as respiration. You will remember that plants can manufacture sugars from carbon dioxide and water. In doing this, they use the energy (the light) of the sun. The sun's energy is locked into the sugar that is built up by photosynthesis.

The energy in a sugar, for example, can be released in a process that is essentially the reverse of photosynthesis, thus:

Sugar + oxygen ⟶ carbon dioxide, plus water, plus energy.

The energy released is heat, instead of light. This is the process of respiration. Actually, the process is a great deal more complicated than we have shown it here. We note simply that respiration frees energy needed for life and growth. You and I, and the higher animals inhale oxygen and exhale carbon dioxide. The actual process of respiration takes place in our lungs.

You will note in the littlec chemical equation above that oxygen is added to the sugar. This adding of oxygen to sugar--or any other substance--is called oxidation. Incidentally, oxidation is one chemical process you can actually see. Burning, say of paper, is the oxidation of the carbohydrate of which paper is made. Oxidation of iron produces rust, and rust is iron oxide.

Summary

So far we have talked about photosynthesis and chemosynthesis; starting from carbon dioxide and water, and leading up to proteins containing additional key elements for their manufacture.

To understand our environment, we need to note several things:

1. Green plants alone (with a few rare exceptions) are able to synthesize simple sugars which are basic to later chemosynthesis. They get carbon dioxide from the air to do this. They get water from the soil. Plants growing in the water use carbon dioxide dissolved in the water, and of course, absorb water directly.

2. One of the products of photosynthesis is oxygen.

3. Both plants and animals, given the simple sugar resulting from photosynthesis, can build many other chemical compounds including carbohydrates, fats, oils, waxes and other materials.

4. Both plants and animals can build proteins, and ultimately protoplasm, the living substance, from carbohydrates and other elements including nitrigen, phosphorus, calcium, magnesium, and sulfur.

This whole building process--synthesis--ties up the elements in plant and animal bodies. Unless there were some way to break down the plant and animal products, all these elements would ultimately be tied up in the dead bodies of plants and animals.

Thanks to the living organisms of the soil, and of the fresh and salt waters of the earth, the complex chemicals of plants and animals that die are broken down again into simpler compounds. Among these are carbon dioxide, nitrogen in the form of nitrates or ammonia, and various forms of sulfur, magnesium, calcium, and phosphorus.

There is another way to look at the whole process of photosynthesis, chemosynthesis, and decay. We could follow various elements as they move into plants and back to the earth or into the atmosphere.

Carbon, for example, moves from the atmosphere into simple sugars, thence into proteins, thence to protoplasm and finally to carbon dioxide again as plants are decomposed. We refer to this as the carbon cycle.

There are others. Hydrogen goes from water into carbohydrates, then proteins and protoplasm, thence back to water again. There is a nitrogen cycle, an oxygen cycle, and so on.

If any of these cycles were to be seriously interrupted, life might not continue on the earth. Suppose, for example, that the decay organisms in the soil were poisoned wholesale by some compound or other that mankind let loose. The result would be an interruption of the carbon cycle, and living things would come to an end. Or, suppose we managed to poison the oceans where floating plants recycle about a third of the carbon in our world. Again, we would expect a serious interruption or breakdown of the carbon cycle on which we--as all other living organisms, are dependent.

Or, suppose the particular soil organisms responsible for nitrate production--and there are not too many of these species--were destroyed by a chemical or by a radio-active substance that humans let loose. Here would be an interruption of the nitrogen cycle that could cause life on this planet to cease.

Now note: No interruption suggested here has taken place. Nor do we believe that it is likely to, just as long as we humans know what we are doing and avoid action that may act against us. What this means is that we need to continue and improve our scientific research so that we can predict with certainty what may happen as we change or manipulate our environment.

We should note that human beings are really not critically necessary or important in the general biological cycle. We exist only because plants provide us the oxygen to breathe and the sugar basic to our living chemistry

Actually, we can say the same thing about all animal life. Animals, either individually or collectively, depend on plants, both for basic sugar and oxygen. It is true that many animals, especially insects, pollinate the flowers of the angiosperms. Birds and rodents disseminate the seeds of many plants. There is a vast complex of these and other interrelationships. Basically however, plant life does not depend on animal life. Although the composition of vegetation would be greatly changed if all animal life were to disappear, nevertheless the planet would continue to be clothed with vegetation. On the other hand, if all plant life were to disappear, animal life would disappear also.

If there is a lesson to be drawn from such considerations, however speculative, it is that we need to be sure we are living in especially good harmony with the plant life on which we depend.

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name: ______________________

Address: ______________________

____

Working Title: ______________________

Unit No. & Title: ______________________

____

Date Submitted: ______________________

Hours Spent on this lesson: __________

(Block below for instructor use)

Date Received: ______________

Date Returned: ______________

Comments:

____
(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 4

BASIC ECOLOGICAL CONCEPTS

Unit No. 4

Basic Ecological Concepts

Reading Assignment:

Read the attached material entitled Ecology first, it will help you understand the more difficult material that follows.

Food chains and webs: Odum, item 4, p. 63 and p. 225
Territory: Odum items 15, p. 209
Habitat, niche: Odum item 1, p. 234
Homeostasis: Odum, item 4, p. 33
Cycles: Odum, item 1, p. 86, item 2, p. 93
Communities: Odum, item 1, p. 140
Succession and climax: Odum pp. 251-269
Ecological balance: Brubaker, p. 83-86
Note additional reading at the end of the problem.

Assignment:

Determine ecological plant succession in your area. See problem for Unit 4 attached. Turn this in with Unit 5.

Problem: (for plant succession) Unit 4

Identify the stages in plant succession from the initial invasion of a bare area to the climax vegetation.

The "bare" area can be either bare rock, a sandy place, a cultivated field, or a pond (preferably a natural one). Choose one, then follow:

General procedure:

Bare rock: Examine the rock or rocks carefully, noting any indication of plant or animal life--such as lichens, mosses, any grasses or forbs. Which takes up residence first? Next? At the base of or in the cracks or crevices of the rocks, note vegetation present. Any way to tell how long before this vegetation will cover the rocks? What plants will follow? What kind of vegetation will be there, ultimately?

Cultivated field: Check fields in your area that were once cultivated (get the dates of last cultivation). Check a 1-or-2 year old field. What plants come in to start a succession? After these pioneers, what comes next--and about when? And next, and next--get these later stages by checking fields cultivated 5, 10, 20, 30 years ago, or earlier if you can find one. What kind of vegetation will be here ultimately? Grassland? Forest? Chaparral? And what will its dominant plants be?

Pond: Study the vegetation in the pond. Fish out some of the water plants. How many kinds? Abundance? (Note that algae are present, usually, in the summertime. These are the real pioneers in a pond, but it takes a microscope to see them, unless you find floating or submerged masses of green "slime" in the pond. These contain millions of individual miscroscopic plants.) Next, note the vegetation around the edges of the pond. How deep is the water where they grow? Can you identify rushes, sedges, cattails? Any shrubs coming in behind these emergent plants. Then what? And next? What kind of vegetation will ultimately grow on the pond site, once it is filled up? And what causes it to fill up? Have you any basis for estimating how long before the pond will fill up?

Sand: (Or gravel-rock fragments) A bit of desert, or spoil from a strip-mine, or a beach along the seashore or a lake edge will do. Check the plants that seem to be invading or pioneering. What comes next--and next, and next. What kind of vegetation will ultimately inhabit this area? How do you know this? How long will it take? And on what basis can you estimate this period of time?

For whatever plant succession you have chosen, try also to note the animal life present at each stage. Include insects, worms, spiders, and other invertebrates. You may need a hand lens for this. Do as much identification as you can, but don't worry about species. Use names such as web-spider, hunting spider (no web), earthworm, insect (butterfly, beetle, ant, etc., if you can). Did any plants or animals formerly live here that are now gone? What happened to them?

For each stage in succession that you can identify, list the kinds of plants and animals present and mark the commonest or dominant ones.

Note: If you live in an area where they occur, you may want to study the succession on an abandoned ant hill, or on a kangaroo rat mound or even a prairie dog mound. Approach any one of these the same way as above, noting pioneers, then successive stages to climax vegetation.

Read the appropriate chapters in Odum's Fundamentals of Ecology (Chapters 11, 12, 13, 14, whichever fits your selected problem, plus in all cases, chapter 9.)

Scientists have been studying the relationships between man and his environment for many years. The more such matters have been studied, the more complex and difficult some of there inter-relationships have proven to be. What we thought were quite simple and direct relations have turned out to have a bewildering variety of indirect side effects. The scientists who study such things--the ecologists--are frequently unable to provide clear and certain answers for our environmental problems.

Even so, ecology, or the ecological way of thinking, has a great deal to offer. No ecologist would claim to be expert in all the many sciences that must often be brought to bear on an environmental problem. But ecologists know how to attack these problems, and they are fully aware of the need for combining forces, so to speak, in attempting to arrive at solutions. They know how to ask the right questions.

Ecologists have a disciplined habit of looking ahead at various possibilities. For example, if we undertake to kill mosquitoes, what other living creatures may be affected? What of the birds or other insects that feed on mosquitoes? What will they feed on once there are no mosquitoes left? How will such changes affect man? Ecologists go on asking questions like these, oftentimes embarrassing questions that may take a great deal of scientific research to answer. We tend to get impatient with people who think this way, especially if there is money to be made in what we want to do. And so, generally, we have not listened to our ecologists. In fact, we have often not wanted to. Frequently, if we did listen, we might take a quite different course, or possibly we might take no action at all.

Many years ago, Charles Darwin, the great naturalist, used to tell a story about ecological relationships. He said that wherever there were old maids, there was likely to be more clover seed. Old maids keep cats. Cats eat mice. Mice eat bumblebees. Bumblebees pollinate clover so that it sets seed. The more old maids there are, the more cats there are. The more cats there are, the more mice they will catch. The less mice there are, the more bumblebees there can be. The more bumblebees, the more clover they will pollinate--and the more clover seed will be produced.

This may sound like a far-fetched story. But actually it is a lot more simple than some of the relationships that have been fairly well worked out.

At first sight the relation between man and his environment appears relatively simple. If you got a disease, you took a medicine that would stop it. If you found an insect pest eating your crop plant, you developed a spray that would kill it. If mosquitoes bothered us, why, we sprayed oil or insect killers on all nearby water areas, and then our summer barbecues could proceed without the pests. We had an idea that for almost any ill that beset us, all we had to do was develop a remedy for it. A sort of one - two operation.

But, as it has turned out things are more complex than that. The fact is that some, indeed most living relationships are not one - two matters at all. Many of our medicines have produced side effects worse than the illness they were intended to cure. Many insect pests were able to survive the poisonous sprays we used; the survivors bred and developed new generations of insects resistant to the sprays. The complex and intricate relationships among living organisms have almost always been extremely difficult to unravel. It has frequently taken many years of patient, expensive study to learn about even the simpler ones. For example, from the time malaria was first reported by Hippocrates in the 5th century B.C., it took humankind 24 centuries to find out what caused this disease and how a man could get it. This disease was possibly the most widespread of all diseases that affect humans. Just at the turn of this century three Italian investigators reported that malaria was probably carried by a certain type of mosquito. Most people know--or think they do--that a certain mosquito carries malaria. But, we know now that there are about 35 different species of mosquito that can carry the disease. They are all anopheline mosquitoes and they are found nearly throughout the world. They are commonest in the tropics, but they are found in the far North as well.

These mosquitoes live and reproduce for the most part in wet places--in streams, ponds, small bits of water. The males live on plant juices. The females live on blood of animals, including man. If they cannot get blood, they cannot produce fertile eggs. They carry four different kinds of parasites--each of which will produce a particular kind of malaria in man. A man can have more than one kind of malarial disease.

This is not too complex perhaps. But there are other kinds of malaria that affect apes, monkeys, birds, and reptiles. And other kinds of mosquitoes transmit these diseases. One may cross-transfer from man to chimpanzee, but this cross-transfer is rare. Even so, we learned much about human malaria by studying malaria in birds, rats and mice.

We attack the parasite--which is a living organism--in man, with drugs. Quinine was and still is widely used. But other, better and newer drugs are now known.

However, we have also undertaken to control the spread of malaria by attacking the mosquitoes. We screen our houses, put screens over our beds--and better yet, we try to destroy the mosquito populations where they breed. We used DDT, dieldrin, chlordane, to kill the juvenile or larval forms of the mosquitoes in the water. This worked pretty well. However, such chemicals also destroy a lot of other animal life. DDT doesn't go away right away. It accumulates in fish, in birds. We eat fish and birds and pretty soon, we have DDT in our systems as well. We didn't intend for this to happen. Many birds may die from eating too many little fish with DDT in them. Ducks die and the sportsmen don't like that. Fish die, and the sportsmen don't like that, either. And pretty soon a government agency condemns fish reared in ponds, for sale. And the fish producers don't like that.

All sorts of bizarre and unexpected things result from our very direct--and "simple"--efforts to control mosquitoes. Legislators become alarmed and pass laws about using chemicals. Various government departments make regulations--and so, on and on, as the inter-lacing network of effects takes place.

There are many other examples we could describe that show how complex the relation of man is to his environment. One of these has to do with Peter Rabbit, who almost became a world-wide problem, and who might yet.

Our domesticated rabbit came originally from Europe. The wild form looks very much like the cottontail of our country, but there is a vast difference between them. The European rabbits dig holes and they live together in large communities. The areas where they live, in an inter-lacing network of underground burrows are called rabbit warrens. American rabbits do live in holes or old logs, but they do not dig holes or burrows of their own. Simple, so far.

In Europe the rabbit was domesticated centuries ago, and there are now many different breeds. It was used as a food, indeed it was and is considered in many places as a great delicacy. Rabbit skins have been used in the fur trade for a long time, and the fur has also been of considerable importance for the making of felt--for hats and other articles. The animals have been common household pets. All told Peter Rabbit is widely known in the world, for one reason or another.

But despite its value as a pet, or fur, or food animal, the European rabbit is a very serious pest of agriculture. Rabbit warrens may be of almost any size, but when they cover hundreds of acres in a badly infested area, the rabbits leave essentially no forage for cows or sheep or other livestock. Any trees present are trimmed up to two feet above the ground, and their bark is gnawed. In such situations agriculture is for all practical purposes impossible. The animals increase rapidly under favorable conditions. They breed 4 to 8 times a year and produce 3-8 young in each litter. They begin breeding at about 6 months of age.

European rabbits have been introduced into many parts of the world, partly for sport, partly for food and fur, and for other reasons. Attempts to introduce them have sometimes failed and sometimes succeeded. They spread over Tasmania about 1830 and widely over Australia beginning about 1859. Some two-thirds of the Australian continent became infested with them. Some 70 million rabbit skins were shipped from Australia annually for a number of years. From Australia the rabbit was taken to New Zealand. There, the early introductions were not successful, but by about 1864 it got going, and within 10 years it has increased enormously. Early in the present century it was carried to Chile in South America where it soon became a serious pest. In the island of Tierra del Fuego off the southern tip of Chile, it reached plague numbers by 1947.

Finally, and ominously, this rabbit is flourishing on the San Juan islands off the coast of the State of Washington. In 1924 a count showed 30 rabbits to the acre. These rabbits have been offered to sportsman clubs and others to "restock" areas where our native cottontails are too few for good hunting. They were called "San Juan rabbits." Thousands were released in various places, but fortunately for American agriculture the introduction did not succeed.

Wherever the rabbit flourished and became a pest, all sorts of efforts were made to reduce the overwhelming numbers. In Australia great barrier fences many hundreds of miles long were erected to stop the spread of the pest. Poisons were used, and these resulted in wholesale destruction of other forms of wildlife. Trapping and shooting were tried and the use of poison gas.

In New Zealand rabbit-proof fences were also erected, and thousands of stoats, ferrets, and weasels were brought in to help control the pest. Local Rabbit Control Boards were set up and a central Rabbit Destruction Council was developed to coordinate the work of the local boards.

By and large all the efforts produced little effect on the rabbit population.

In the meantime in South America a disease wiped out nearly all the rabbits that were being used in experimental work in a laboratory in Montevideo, Uruguay in 1896. Later on the disease flared up among domestic rabbits in Argentina, Brazil, and southern California. The death rate was better than 99.5 percent, that is, only one rabbit in 200 survived. This is far more deadly than cholera or plague. The disease was caused by a virous, and was called myxomatosis. It was found to be spread by fleas and mosquitoes. It was also found to have no effect on American rabbits or on other domestic animals, or man. Quite naturally, once these facts were known, attempts were made to introduce myxomatosis into Europe and Australia, but without success.

And then, in 1950, the Australian government decided to try once more. Infected rabbits were let go in seven locations. Nothing happened in six of these, but the disease flared up in one area and began to spread rapidly. Within a half-dozen months, the disease had covered more than a million square miles and by 1956 most of the enormous population of rabbits in Australia had been wiped out.

The Australians were elated. They figured that the increase in sheep production was worth 50 million pounds a year--because the rabbits were gone that formerly ate so much of the forage on which the sheep could otherwise feed.

In New Zealand the myxoma virus didn't work, apparently because there are no carriers. And thus, at great expense to the government, airplanes fly up and down the ravines, scattering poisoned carrots. They are followed by hunters with dogs, flame-throwers, and guns to wipe out any remnants. Forage improvement is noticeable almost at once.

In 1952 a retired physician in France inoculated two rabbits with myxoma virus and let them loose on his estate near Paris. By 1956 about nine-tenths of the wild rabbits in France were gone. The disease spread widely in Europe. It reached England in 1953 and by the end of 1954 was distributed throughout England and Scotland and Wales with some areas unaffected. By 1956, about 99 percent of all rabbits in Britain were gone.

The disease was introduced in Tierra del Fuego in 1953 and within two years the population was substantially reduced.

For awhile, it looked as though myxomatosis had solved the problem of excessive rabbit population except in New Zealand. Farmers could breathe easier. The pest was apparently dead and gone.

But the kill was not 100 percent. It was 99.5 percent. A tiny fraction of the population of rabbits survived. One rabbit in 200 did not die--and there were millions of rabbits. And gradually, since the great epidemic in Australia, the disease-resistant rabbits have come back, slowly, locally. The scientists believe that the population has reached about 10 percent of what it was, and that it has stabilized at this level. Perhaps it has. Perhaps it has "stabilized" because rabbit control boards of one kind or another continue with poison, shooting, trapping, fencing, and other measures. Or perhaps all these measures are not needed. In the meantime, scientists are working to produce more virulent strains of the myxoma disease. Almost certainly, we have not seen the last of the Peter Rabbit in Australia, certainly not in New Zealand, and just possibly not in the United States. Some irresponsible person may yet succeed in getting the European rabbit to live and breed successfully in some part or another of America. And away we go!

One series of relationships that we will need to keep in mind is known as a food chain. We can illustrate a food chain by a simple example.

1. Simple, floating, microscopic plants (plankton) in a pond are eaten by microscopic animals.
2. The microscopic animals (nekton) are fed upon by small, water-living insects and other tiny animals, such as crustaceans.
3. The water insects and crustaceans are eaten by small fish.
4. The small fish are eaten by larger ones.
5. The larger fish are caught and eaten by fish-eating birds, or perhaps by human beings.
6. The fish-eating birds are killed and eaten by foxes or by hawks.
7. The foxes are killed and eaten by bears or lions.
8. The lions or bears or hawks die and are fed upon by soil organisms that release chemical materials. These materials may get into streams and thence into ponds where they are used by plankton.

There are hundreds of such food chains known, and probably many thousands that have not been studied.

Human beings enter such a food chain at various points. We may catch and eat the larger fish. Or, we may shoot the birds that feed on the fish. Or we may shoot the bears or lions that feed, in part perhaps, on the fish-eating birds.

There is one more set of interrelationships we need to know about. This is the matter of plant succession. It works like this:

1. We start with bare rock. Over a long period, with freezing and thawing, rain and snow, the rock begins to crumble and to go to pieces, at least on the surface.
2. In the decomposing rock, lichens start to grow.
3. After a while (years usually) mosses appear and grow.
4. Mosses and lichens grow and die and add a little organic material to the softening rock.
5. A grass or two, or a flower may get a start.
6. Grasses and other herbaceous plants get a pretty good foothold and begin to build a thin layer of soil.
7. Shrubs start up--from seeds blown in or carried in by animals.
8. Trees come in later, as soil is built up.
9. The kinds of trees change. Earlier pioneers are replaced by trees that could scarcely start on thin poor soils, but that can get going on soils built up by the pioneers.
10. Ultimately, where there was once only bare rock, there is a luxuriant forest, perhaps many years or centuries later.

We could have started this plant succession with a pond. Water plants, shore plants, shrubs, then trees, might form the succession in such a series--or sere, as the ecologist calls them.

If the sere developed in the grasslands, the ultimate stage would be prairie grasses, rather than trees.

Once a succession or sere is interrupted--for example by the cultivation of land for crops--the plant succession comes to a halt. It stays that way until the interruption stops-for example, a farmer stops cultivating a field. Then what is called a secondary succession takes place--for example:

1. Cultivated field
2. Annual weeds and grasses of many kinds
3. Perennial, longer-lasting weeds
4. Shrubs (such as blackberries)
5. Trees of a pioneer sort (such as hawthorns or red cedars)
6. Forest of trees and shrubs
7. Climax forest

We have used a new term here--climax. This is the association of plants that will keep on reproducing itself as long as the climate doesn't change. In this case, it might be a sugar maple--beech forest typical of many parts of New England. Or it might be a douglas fir --western cedar forest. Depends on the climate and geographical area. (See Odum, p. 264)

You can see secondary successions starting on road cuts, paths through fields, banks, even piles of dirt excavated from a building. First come annual (1 year) weeds, then perennials (dandelions, plantains) then shrubs (blackberries) then trees--providing the disturbed areas are left alone long enough. (See Odum p. 261)

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name:______________________________

Address:____________________________

____

Working Title:______________________

Unit No. & Title:____________________

____

Date Submitted:_____________________

Hours Spent on this lesson:________

(Block below for instructor use)

Date Received:______________

Date Returned:______________

Comments:

____
(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 5

THE ATMOSPHERE

Unit No. 5

The Atmosphere

Reading Assignment:

The Atmosphere and Life by Van Dersal
Odum, p. 86-99, 444-445
Air Pollution Primer by Corman
Wagner, Chapter 10
Brubaker, pp. 87-96, 149-156

Assignment:

Turn in report begun with Unit 4.

Our earth, as a planet, is believed to have originated about 4.5 billion years ago. At the time this took place, the crust of the new planet was composed almost entirely of solid rock; it had no atmosphere surrounding it, as it does today. But by about 3 billion years ago, or possibly a little before that, an atmosphere of sorts had developed. This was quite different from the atmosphere we know now. There was no free oxygen in it; rather it seems to have been made up mostly of methane, ammonia, nitrogen, carbon monoxide, hydrogen, and water vapor. Other gases, poisonous to life, were present also, such as chlorine and hydrogen sulfide. There were, of course, no living things present at all.

How can we possibly know these things billions of years later may seem very remarkable. Such facts as we have, have been worked out by hundreds of chemists, biologists, physicists, geologists, astronomers, and others. Through their painstaking studies we have learned a good deal about the composition of the sun and of our planet. The rocks laid down millions or billions of years ago have been examined for any evidence of living things. We were looking for any fossils, even microscopic ones, or for any evidence of the chemicals that are characteristic of living things. The scientists making such studies are the first to admit that there are simply enormous gaps in our knowledge. But gradually the facts have added up and our understanding has increased. What we have said in the first paragraph above, as well as what follows next, is based on very careful work and very cautious conclusions about what has been discovered.

To return to the planet's first atmosphere, at the time it was developing, as from the very beginning, ultra-violet radiation from the sun was reaching the surface of the earth. The first atmosphere would not screen these harsh rays, which would have killed any living thing exposed to them. However, the ultra-violet light, or perhaps electrical discharges, or both, had a very remarkable effect on the gases of the early atmosphere. They caused such chemicals to combine in various ways and to form complex substances including amino acids. These same combinations have been successfully made in the laboratory. They have also been found to take place in meteorites from elsewhere in our solar system or even from outside it.

The amino acids formed in such a way are of great importance. They are complex chemicals themselves, but even so, they combine under the right conditions to form proteins, which are still more complex. The amino acids are often spoken of as the "building blocks" of proteins. And, it is the proteins that combine to form protoplasm, the living substance of the human body as well as of plants and animals.

The studies made so far lead to the belief that some very simple living organisms developed, probably in the lower levels of pools or bays. There, they would be safe from the deadly ultra-violet. They are thought to have lived by a process of fermentation on the organic materials sinking down to them. These materials were the amino acids and other substances developed from the ultra-violet irradiation of the atmospheric gases above.

These oldest organisms of the fermenting type were something like the minute, spherical bacteria of the present day. They were microscopic, very simple, very primitive, one-celled, sexless, and unable to manufacture their own food. We are not sure that the oldest fossils discovered in the geological record are these first organisms. The very oldest such fossil existed about 3.2 million years ago. Whether it is indeed one of the oldest forms, or a form that developed a little later is not certain.

Incidentally, such dates as the one just mentioned have been worked out by some very ingenious methods. Various radioactive substances that continue radiating for hundreds of millions or billions of years can be used to determine the age of a given rock in which a fossil is found. The rate at which the element's radioactivity decays is known, and this can be used as a measure of length of time it has been in the rocks in which it occurs.

The very oldest organisms probably developed longer ago than 3.2 billion years. We are not sure. But by that date a new kind of life had developed, and we have found fossil forms of it. It was still one-celled and sexless, but it was able to do two new things. It could form simple sugars by photosynthesis, and it could use nitrogen directly to help form its own amino acids. These still microscopic forms, that is to say, could manufacture their own food and were no longer dependent on the amino acids created in the atmosphere.

Now in photosynthesis, as we have already noted, oxygen is given off as a by-product. Thus for the first time, a little better than 3 billion years ago, oxygen began to be added to the environment.

Very gradually this life form with the new powers began to change. One-celled to start with, it began to develop chains or plates or clusters of cells held together. These many-celled organisms have been identified in many of the older geological formations. A number of different kinds were present about 2 billion years ago, and hence are believed to have developed well before that time. They resemble very closely the plants we know today as blue-green algae. They may, in fact, have been the ancestors of these microscopic blue-greens.

During the next billion years, that is, between 2 and 1 billion years ago, still a third kind of life developed. This third form was still microscopic and it could manufacture sugar (and oxygen) by photosynthesis. But, it had a nucleus, which was a new and very important development. It resembled present-day plants known as green algae.

Almost all plant and animal cells have a central body, rich in special proteins, known as a nucleus. A nucleus makes sexual reproduction possible, and hence much greater diversity among living forms. All living organisms whether single-celled or many celled, possess this nucleus, all, that is, except the bacteria and the blue-greens. This is one reason why these two groups of organisms are considered the most primitive of all. The other reason, as we have seen, is that bacteria and blue-greens appear first in the geological record.

As the blue-green and green algae developed (or their ancestors did), they continued to add oxygen to the environment, by photosynthesis. About one billion years ago, or a little less, the oxygen given off by these organisms reached about one percent of the amount in the atmosphere now. This was a most significant point, since at this concentration of oxygen enough ozone is developed (through the action of sunlight on free oxygen) to screen out most of the ultra-violet rays that would otherwise have killed living organisms.

Thus, in about two billion years of evolution, the oxygen-producing organisms replaced the primitive fermenting types as the dominant life forms of the earth. Oxygen was in fact, a major pollutant of the earlier atmosphere. The change to oxygen-producing forms is considered by many scientists as one of the greatest biological revolutions in the history of our planet.

The green algae continued to increase and to add oxygen to the earth's atmosphere. To start with they were single-celled organisms. But about 600 million years ago, in what the geologists call the Cambrian period, multi-celled green organisms began to appear. This, too, was a tremendous evolutionary step.

About 400 million years ago plants and animals, many-celled by that time, began to come out of the primordial waters and to invade the land. Insects appeared about this time also.

About 100 million years ago flowering plants began to appear. Mammals preceded them by possibly 50 million years. Twenty million years ago mammals began to diversify, and what are known as hominids appeared; these were the precursors of man. At about the same time the level of oxygen in the atmosphere reached the amount present now.

Human beings, as we know them now, appeared about two million years ago.

In summary we can say:

1. The planet earth originally had no atmosphere.
2. Its first atmosphere contained no oxygen.
3. The first organisms lived, probably, by fermentation.
4. The first organisms were replaced by later organisms that produced oxygen as a by-product of photosynthesis.
5. Oxygen was a pollutant of the earliest atmosphere, and the oxygen-producing organisms became the dominant life forms early in the history of our planet.
6. When enough oxygen had been produced, the ultra-violet radiation of the sun was effectively screened off.
7. Once the ultr-violet could no longer reach the earth, living forms became more complex and diverse.
8. Ultimately, multi-celled forms invaded the land.

9. Plants and animals differentiated and populated the land masses, and the waters of the earth.

10. Man himself developed at the evolutionary end of a long line of mammals, then hominids, in an atmosphere containing oxygen essential to him, created by plant life as one of the products of photosynthesis.

From all this we may conclude that:

1. Man is completely dependent on the plants in his environment, both in the oceans and on the land, for the atmosphere that sustains him, no less than for the food the plants manufacture.

2. Man is a product of the natural environment in which he lives.

The atmosphere of the present day--the air we breathe--is a mixture of gases. It is not a chemical compound. It penetrates the soil, and it forms an envelope several hundred miles high around the earth. But some 95 percent of this is in a layer about 10 miles thick. This layer of air--called the troposphere is thickest at the equator (10 to 12 miles) and less thick toward the poles (5 to 8 miles). The weight of this mass of air is about 15 pounds per square inch, or better than a ton per square foot at the earth's surface.

The air of the troposphere contains a number of different gases. Most abundant is nitrogen which makes up 78.09 percent of the air by volume. Oxygen is next in volume with 20.94 percent. Adding these two together gives us 99.03 percent.

The gas, argon, is present to the extent of .93 percent. Carbon dioxide is next with .03 percent. Twelve other gases make up the rest, that is, the remaining .01 percent. The table shows all these, in terms of percentage and also in parts per million (ppm).

Besides these gases, the air contains anywhere from 1 to 3 percent of water vapor. And then, floating in the air are small particles of many substances. These are usually called particulates, and as we shall see later, they play an important part in some of the processes going on in the atmosphere.

As we have noted, carbon dioxide composes a rather small part of the atmosphere, that is, about .03 percent, or 320 parts per million at the present time. Ordinarily we do not think of this gas as a pollutant. It is used by plants in the photosynthesis of sugars, though, and is most important in the living cycle. As a very rough estimate, about 3 percent of the world's supply of carbon dioxide is used annually by the plants of the world. About the same amount is returned to the atmosphere by the processes of decay.

But we humans have been adding carbon dioxide to the atmosphere in enormous amounts in recent years. We have been releasing carbon from the burning, or oxidizing of coal, oil and gasoline. These substances were formed many millions of years ago during the Carboniferous period. Carbon dioxide may have been more abundant in the atmosphere then, than now. At the time enormous quantities of plants flourished, died, and then were compressed and converted into peat, coal, and petroleum by geologic action. This process tied up immense quantities of carbon that have been out of circulation for million of years. Our use of coal and petroleum products--the so-called fossil fuels--is what has been adding oxidized carbon, that is, carbon dioxide, to the air.

Within the past century the amount of carbon dioxide in the atmosphere has increased from 290 parts per million, to 320 ppm today. This is a fairly substantial increase. Many scientists think this increase is largely responsible for an increase in the temperature of the earth's surface, up to about 1940.

The increasesin carbon dioxide are enough to affect our climate, noticeably. This gas lets the short wave-length ultra-violet radiation from the sun pass through. But the long wave-length, infra-red radiation (actually heat-energy) emitted by the earth is radiated back to earth by carbon dioxide. The total effect is to cause the earth's temperature to rise. If the carbon dioxide content increases by 10 percent, the effect would be to raise the earth temperature by a half a degree Centigrade.

Between 1880 and 1940 the average temperature of our earth rose about 0.4° centigrade. Very possibly this was caused by an increase in carbon dioxide. However, there were other factors at work. The temperature of the earth began to fall after 1940, and by 1967 it had dropped by 0.2° centigrade. Increasing dust and aerosols in the atmosphere may explain this drop in temperature, but scientists are by no means certain of this. It appears at the present time that we do not really know about either point--carbon dioxide and a rise in earth temperature, or dust and aerosols and a decline in earth temperature. Scientists point out that until we have more accurate measurements over a longer period of time, we cannot reach clear conclusions about the climatic changes.

Particulates is a term used to describe airborne particles. Usually people think of these simply as dust, but there is more to it than that. Some particles are large enough to be seen, and these are what we call "dust" in the air. But many particles are too small to be seen. Some are extremely minute, consisting of only a molecule or two of a substance. These tiniest bits of material are called aerosols since they remain floating in the air and move about in the wind just as gases do.

In order to get an idea of the size of airborne particles, we need to become familiar with the micron--a unit of measurement used for very small things. One micron is 1/1,000 (one one-thousandth) of a millimeter or 1/25,000 of an inch. Many bacteria are 1 to several microns in size, and of course, you cannot see these. The human eye can see particles only when they are 10 microns or more in size.

Things in the air that we can see are raindrops and most fog droplets. Raindrops are 400 to 5,000 microns in size. Fog droplets measure from 5 to 60 microns. Smoke consists of both solid and liquid particles less than 1 micron in size. You can see a cloud of smoke, but not the individual particles. Dust particles are generally more than a micron in size. Mist consists of liquid particles up to 100 microns in diameter. Aerosols, as we noted already, are very tiny, ranging from a ten-thousandth to a tenth of a micron in diameter (0.0001 to 0.1 micron). Obviously, smoke will contain aerosols as well as larger particles.

Despite the small size of particulate matter, the concentration in the air of particulates may be tremendous. Over heavily polluted cities, 50 to 100 tons or more of particulates may fall out of the air on each square mile of surface. The larger the city, generally, the greater is the concentration of particulate matter. Concentrations of a hundred billion particles per cubic yard may occur.

The aerosols act as nuclei on which water vapor condenses very easily. They are thus very important in the formation of mists, fog, and rain. About half the particles in the air over cities are less than 2 or 3 microns in size. When we inhale these particles, they can reach that part of our lungs that unprotected by mucus. If they are carrying harmful chemicals--such as sulfur dioxide for example--we may begin to have difficulties with our breathing.

Particulates enter our atmosphere at the rate of some 12 million tons per year. About half come from industry, about a fourth from power plants. About a million tons apiece come from automotive vehicles, refuse disposal, and heating plants.

It is clear that we are pouring vast quantities of pollutants into the atmosphere. We are much less certain about the effects they may have, both on our environment and on us. Some of the chemical compounds can cause cancer. Some can kill human beings but only if they are concentrated enough. Some can kill vegetation. Some cause irritation, coughing, choking, headache, and fatigue. Some deteriorate fabrics, rubber, even building stones. Some are poisonous not only to man but to other organisms. Many of these may be washed down by rain into the soil, the rivers, and the ocean, there to poison fish, birds, mannals, or microscopic organisms of many kinds. Because these pollutants are increasing, we need to study their effects and take steps to cut back on the ones that are most dangerous either directly to us or to our environment and thus indirectly to us.

We used to mean by "smog" a simple mix of smoke and fog. But we now mean something else--namely some products that are produced by the action of sunlight on some of the chemicals in the air. This photochemical smog is most complex. Hundreds of chemical reactions take place, involving oxygen, hydrocarbons, nitrogen dioxide, ozone, and other substances. The resulting witches' brew produces a whole series of chemicals we did not release as such, but that are formed nevertheless under the radiant energy of the sun. This photochemical reaction is reminiscent of the action of ultra-violet on the world's first atmosphere.

The relation to human beings of these released and developed chemicals to our health, for the most part is unknown. It is fairly clear that their concentration is important, that is, in the air over cities the concentrations may be high--and troublesome or even disastrous. In areas far away from cities, the concentrations are low enough so that no serious effects may take place--as far as we know at present.

There have been several notorious air pollution disasters. The first of these took place in 1930 in the Meuse Valley of Belgium. This heavily industrialized, 15-mile long valley was blanketed by a thick cold fog in December. Thousands of people became sick; about 60 people died. Most of those who died were older people and those who were already ill from heart or lung diseases.

Then, in 1948 in Donora, Pennsylvania, some 6,000 people fell ill; twenty people died. And in 1952 London experienced a smog that killed about 4,000--mostly elderly people or those with preexisting heart or lung conditions.

Less well-known are the disasters in New York City in 1953, 1962, 1963, and 1966. Hundreds of people died at these times as a direct result of heavy air pollution.

We should note here that soil blowing is involved in the air pollution problem. We do not experience soil blowing the year round, of course, but primarily in the spring months after bare soil has dried out and is in a condition to blow. High winds do the rest. Very large tonnages of soil particles are added to the atmosphere during these seasons. The matter has not been too well studied, hence the fate of the finer particles is not certainly known. Larger particles come down soonest, sometimes forming dunes. Records indicate that soil dust may be blown several thousand miles before settling out, but how long the finest particles remain in the air is not known.

Soil blowing is most common in the Great Plains if no soil conserving measures have been applied. But the phenomenon is not confined to that area. Blowing of soil, or wind erosion, may occur anywhere if soil is bare and dry, and winds are strong. Notable are such areas in Michigan, Long Island, California, and other states.

Table 1

Composition of clean, dry air near sea level

COMPONENT	CONTENT % by volume	CONTENT ppm	COMPONENT	CONTENT % by volume	CONTENT ppm
Nitrogen	78.09%	780,900 ppm	Hydrogen	.00005%	0.5 ppm
Oxygen	20.94	209,400	Methane	.00015	1.5
Argon	.93	9,300	Nitrogen dioxide	.0000001	0.001
Carbon dioxide	.0318	318	Ozone	.000002	0.02
Neon	.0018	18	Sulfur dioxide	.00000002	.0002
Helium	.00052	5.2	Carbon monoxide	.00001	0.1
Krypton	.0001	1	Ammonia	.000001	.01
Xenon	.000008	0.08			
Nitrous oxide	.000025	0.25			

NOTE: The concentrations of some of these gases may differ with time and place, and the data for some are open to question. Single values for concentrations, instead of ranges of concentrations, are given above to indicate order of magnitude, not specific and universally accepted concentrations.

SOURCE: "Air Chemistry and Radioactivity," Junge, C. E., Academic Press, New York, 1963, p
"Air Pollution," Vol. I, 2nd ed. Stern, A. C., Ed., Academic Press, New York, N
1968, p. 27.
"Sources, Abundance, and Fate of Gaseous Atmospheric Pollutants," Robinson
Robbins, R. C., Prepared for American Petroleum Institute by Stanford Research Institute, Menlo Park, Calif., 1968.

National air pollutant emmissions, millions of tons per yr. (1965)

	Totals	% of Totals	Carbon monoxide	Sulfur oxides	Hydro-carbons	Nitrogen oxides	Particles
Automobiles	86	60%	66	1	12	6	1
Industry	23	17%	2	9	4	2	6
Electric power plants	20	14%	1	12	1	3	3
Space heating	8	6%	2	3	1	1	1
Refuse disposal	5	3%	1	1	1	1	1
Totals	142 million		72 million	26 million	19 million	13 million	12 million

SOURCE: "The Sources of Air Pollution and Their Control," Public Health Service Publication No. 1548, Government Printing Office, D. C., 1966

Air Pollution Disasters

Date	Place	Mortality
February, 1880	London, England	1,000
December, 1930	Meuse Valley, Belgium	63
May, 1934	Great Plains to eastern seaboard	Not known (First great dust storm)
March, 1935	Great Plains to eastern seaboard	Not known (Second great dust storm)
October, 1948	Donora, Pennsylvania	20
December, 1952	London, England	4,000
1953	New York City	"Hundreds"
January, 1956	London, England	1,000
December, 1957	London, England	700 - 800
December, 1962	London, England	700
1962	New York City	"Hundreds"
1963	New York City	"Hundreds"
1966	New York City	"Hundreds"

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name:______________________________

Address:___________________________

____

Working Title:______________________

Unit No. & Title:____________________

____

Date Submitted:_____________________

Hours Spent on this lesson:_________

(Block below for instructor use)

Date Received:_______________

Date Returned:_______________

Comments:

____
(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 6

SOILS

Unit No. 6

Soils

Reading Assignment:

Life in the Soil, by Van Dersal
Odum, p. 128 - 131 (See also his listings in the index under bacteria, fungi)
p. 368 - 374

Potentially Arable Soils of the World and Critical Measures for Their Use, by Kellogg and Orvedal.

Brubaker, pp. 119-133

Assignment:

Check the macro-organisms in humus. See problem for Unit 6, attached.

Soil

Ever since our remote ancestors discovered that seeds planted in the earth would sprout and grow to produce food. we have been interested in the soil. We now understand the basic importance of soil, producer either directly or indirectly of most of the food we eat.

Paper-thin in relation to the land mass itself, soil is a layer of material containing within itself complexities we are a long way from understanding. It supports an almost fantastic array of living organisms, most of them visible only under a microscope. It is asthough there existed a veritable jungle of plants and animals under our feet.

Soil is composed of mineral matter, organic matter, water, air and the organisms that inhabit it. The mineral matter is present as particles of gravel, sand, silt, or clay. The largest particles are gravel and coarse sands. Fine sands, silt, and clay, in that order, are smaller and smaller. Clay particles, for instance are less than two thousandths of a millimeter in diameter. The spaces or pores between these particles are filled with water or air, depending on whether the soil is wet or dry. Even when the soil is apparently dry, each soil particle may have a thin film of water around it.

Mixed with the minerals are particles of organic matter -- remnants of the dead bodies of plants or animals. It is the organic matter that causes soils to be brown or black in color, and this dead material is of great importance, as we shall see. Living within the pores between the mineral and organic particles are the literally countless creatures, mostly microscopic, that bring about chemical, physical, and biological changes in the soil jungle.

From such examples as these--and there are a great many more that scientists have produced--it is clear that the macrofauna of the soil have a great deal to do with soil condition. These are the animals that macerate and digest the dead plant and animal materials reaching the soil. As they burrow and dig, they mix the digested material with the soil. As they do this, micro-organisms work on the digesting material and on the excrement, or casts, of the larger forms. Between them the macrofauna and the micro-organisms conduct the decay process to the end of the decay assembly line.

There are two general groups of organisms in the soil. One group consists of bacteria, plants, and animals that cannot be seen except under a microscope. These are the micro-organisms. Sometimes they are called microbes.

(The second group consists entirely of animals, and most of them can be seen with the naked eye. This is the macrofauna, treated later on.)

--The Micro-organisms

Most of these live in the water-films surrounding the soil particles. A few inhabit the air-spaces in between. These organisms are too small to have any mechanical effect on the soil particles or the spaces or pores in between them. They cannot, that is, actually move the particles or enlarge the pores.

Included in this group are the bacteria, the microscopic algae and fungi, and the microscopic animals such as protozoa, rotifers, and nematodes. Besides these there are actinomycetes, slime-molds, and some other forms. Most of these names may be unfamiliar, but they are explained in succeeding pages.

Some of the organisms are found as individuals; some occur in clusters or colonies. Some move about; some do not. Some kinds may take several forms and perhaps resemble other species. There is tremendous variety among them. They are difficult to observe and study even under a microscope. After all, the soil itself is opaque and most of the organisms in it are transparent or translucent. Many have been studied by getting them to grow in the laboratory on gelatin-like material containing various food substances.

Because these micro-organisms are so small, enormous numbers of them can be present in a small pinch of soil. Usually their numbers are expressed as so many per gram of soil material. Even this is pretty unsatisfactory though, because the numbers or populations vary so much. A few billion may be present in a gram of soil, but a nearby gram may contain 10 billion or more. These numbers vary with the amount of water present, the amount of food, the temperature, and many other factors.

Despite their small size, the micro-organisms have a tremendous effect on the soil as well as a vital effect on the total environment of the earth. It has taken many years to work out what we know about the importance of the micro-organisms. You cannot see the chemical reactions taking place, and finding out what is actually going on has run up against a myriad of technical difficulties. Very gradually, these problems are being solved. Life in the soil, especially the microscopic life, is problably less understood than any other life on earth.

Actinomycetes

Intermediate between the bacteria and fungi in the soil is a group of organisms known as Actinomycetes. Soil biologists have had a bad time trying to classify these things. They are now believed to be the most closely related to bacteria, but they produce long thread-like filaments, or hyphae, very much like many fungi. They occur commonly in colonies that develop a mass of branching hyphae known as a mycelium.

These curious plants are widely distributed in the soil. They are more common in dry, warm areas, and thus their numbers increase from north to south. Their numbers rise dramatically -- up to 10 billion per gram -- in the high temperatures of rotting manure, compost piles, and the like. Also, the greater the humus content of the soil, the more actinomycetes may be present.

These organisms decompose dead plant and animal material, much as bacteria do. They are especially good at decomposing the more resistant parts of plants (such as cellulose) or of animals (such as chitin). Possibly they are most important in the later stages of decay, after bacteria and fungi have decomposed plant and animal parts not as resistant as cellulose or chitin. Some feed on bacteria and some feed on fungi.

Many of the actinomycetes produce antibiotics -- chemical substances that are capable of destroying bacteria. These antibiotics, incidentally, are very important to us. Streptomycin is one, aureomycin, and tetracycline are others that may be familiar to you as one of the so-called "wonder drugs." These and a number of other antibiotics are produced by these organisms as well as many vitamins, all of them used commercially.

Bacteria

By far the commonest living organisms in the soil are the bacteria. They are also the smallest forms, seldom longer than 4 or 5 microns. In a single gram of soil there may be 1 to 3 billion of the microscopic cells. Some measurements show less, some show up to 10 billion. A good figure to use is 2 billion per gram. Not all of these are active; some are resting or dormant.

In an acre of soil 6 inches deep, 2 billion bacteria per gram will weigh about 4,000 pounds or 2 tons. This figure could go as high as 10 tons for short periods in very rich soils.

In ordinary soils, most bacteria are found in the upper 6 inches. The deeper the soil, the fewer the bacteria. This is because there is more humus, or organic material, in the upper layers. The more humus there is, the more bacteria there will be. Bacteria are also present in greater numbers in the neighborhood of plant roots.

Bacteria are everywhere, so to speak. They increase by simply dividing in two. They are present in hot, dry, desert soils as well as in frozen areas of the Artic. Wherever they are, most of them are either microscopically small rods or spheres. A very few are spiral-shaped.

But how big bacteria are (or really, how small) or how much they weigh per acre, or even where they are found, doesn't tell us much about them. What is most important is what they do in the soil.

By far the most bacteria live on organic material, that is, the dead parts of plants or animals. All organic material contains the element carbon, which is an essential part of all proteins as well as the living substance, protoplasm itself. The bacteria that live on organic materials cause decay--meaning these organisms are using organic substances as food.

In the business of decomposing organic materials, the various kinds of bacteria are "fiercely competitive" as one scientist has put it. One micro-organism may feed upon one kind of chemical. Another may feed on a different one, but frequently several types may feed on the same substance--and the resulting competition may result in one victor among the antagonists.

In any event, the breakdown of dead tissues of leaves or animal bodies involves a highly complex series of chemical reactions--not yet very well understood. Here we may note simply that as organic material is assimilated, carbon dioxide is released.

It takes only a few weeks for a leaf to decompose in the tropics, perhaps a year for a leaf to decompose in the temperate area, or as much as 9 years in a conifer forest.

Sugars and starches and pectin go first. Lignin, waxes, cellulose, and chitin go later. The dark material that results is called humus. Not only bacteria are involved; fungi, actinomycetes, and many other organisms play a part in decomposition.

Step by step the breakdown or decomposition proceeds. One organism after another may play its part in a sort of assembly line of decay. As the decay proceeds, many by-products are produced, such as carbon dioxide, methane, various acids, and other chemical substances known collectively as waste products. Very large quantities of carbon dioxide are released to the air as we have already noted.

But not all bacteria live on organic material. Some can get the carbon they need directly from carbon dioxide in the air. Just as all green plants can use carbon dioxide to make more complex compounds, so can certain bacteria. In both cases, the plants and these bacteria can manufacture foods from water and carbon dioxide in the presence of sunlight.

But besides these, there are some bacteria that can use carbon dioxide without any sunlight at all. They get the energy to do this by using ammonia or nitrites or sulfur compounds, or ferrous iron, or hydrogen, or carbon monoxide. They are able to oxidize such materials, and in the process get the necessary energy to synthesize or build carbon compounds, such as proteins or living protoplasm. Not all of these bacteria can do all of these things. One kind works on ammonia, producing nitrites which are worked on by others to produce nitrates. Nitrates can be used by green plants--grasses, shrubs, trees-- and it is from nitrates that the familiar plants around us get their nitrogen for building proteins and protoplasm. This may seem somehat mysterious, but it really is not. When you oxidize sulfur you add oxygen to it and in the process energy is released. When you oxidize ammonia, you add oxygen to it and get nitrates, and in the process energy is released. Only a few kinds of bacteria can do this sort of thing, but they are believed to be of great importance in the world.

Nitrates

Nitrates are chemical substances that contain two parts of oxygen for one part of nitrogen. They may be combined chemically with many other elements--for example, sodium nitrate, calcium nitrate, ammonium nitrate , and many others. The point about nitrates is that they are all directly useable by higher plants for the formation of proteins. Furthermore, the nitrates dissolve in water. This means that the roots of higher plants can absorb them from the soil where they occur in watery solution.

This is the principal way that the higher plants get their nitrogen. The higher plants cannot use nitrogen itself, even though the atmosphere contains so much of it. They cannot use it in the form of ammonia--which contains nitrogen combined with three parts of hydrogen. The only way the higher plants can use nitrogen--which they must have to manufacture protein and protoplasm--is as nitrates.

With this in mind, we can see why the decay processes that produce nitrates are so important. The microbial action that produces them plays a key or critical role in keeping living things--the higher plants, animals, and man--supplied with the essential element nitrogen.

As it happens, there is one other way that nitrates are formed. Some of the microscopic organisms in the soil can develop nitrates by using the nitrogen of the air, directly. This is called nitrogen-fixation. The most important nitrogen-fixing organisms are certain bacteria, as far as we know now. But there are others. Some yeasts can do this, some blue-green algae can, and a few of the filamentous fungi. We are not sure exactly what this means except in some special circumstances. The decay processes seem to be by far the most important in producing nitrates and carbon dioxide. Nitrogen-fixers apparently perform a secondary and possibly local role.

The fungi

Scientists do not know as yet, how many different kinds of fungi live in the soil, although they probably number in the many thousands. Because of the way these plants grow, it is not practical to try to estimate how many there are per unit of soil. In a general way, fungi make up the largest part of the total mass of living material in the soil.

Fungus filaments, or hyphae, cannot be seen by the naked eye, only by means of a microscope. But these threads penetrate the soil in every direction, branching and interlacing to form a mass or mat known as a mycelium, and this you can see. The fungi feed on organic material, and the more of this there is, the more fungus growth there will be. The fungi must also have oxygen in order to exist, which is one reason why fungi are generally concentrated in the surface few inches. It is also in the surface layer that most dead leaves, dead insects, and other dead organisms are to be found.

Fungi or molds are plants, but they are not green, that is, they contain no chlorophyll, the pigment that all green plants have. The fungi depend for their food, just as we do, on the materials such as sugars and starches already manufactured by green plants. They depend as we do, on protein materials already manufactured by green plants or by animals. From the sugars and starches and similar substances the fungi get their carbon. From the proteins they get their nitrogen. All living protoplasm, plant or animal, requires both carbon and nitrogen in its chemical structure.

A few species of fungi are predators--that is, they feed on other living organisms. Some species feed on protozoans. One species is known that sets traps for microscopic worms, or nematodes by developing a little ring of its filament, comfortably large enough for the worms to swim through. Once a nematode is within the ring, the ring suddenly tightens, in about a tenth of a second, catching the worm. Then a fungus hypha penetrates the luckless creature and digests the interior. If the nematods struggles hard enough to break the ring off the hypha, no matter, the ring sends a hypha into the organism and digest it, later sprouting a further thread or filament.

A very few fungi are true parasites, that is, they live within other living organisms. Even these though, if their host dies, can persist in the soil or elsewhere. These are the fungus diseases. Incidentally, fungi are quite capable of parasitizing one another.

Some fungi form an association with plant roots, known as a mycorrhiza or fungus root. The hyphae either form a sort of mantle around the ends of the roots or it may penetrate the roots at the tip and live inside. The tree supplies the fungus with carbohydrates (sugars, starches, etc.) and possibly other substances. It is not quite clear what the tree or shrub gets in return, but some trees won't grow unless they have the fungus on their roots.

All of the fungi reproduce by means of spores. Some of the fruiting bodies are small and simple--others are large and complex. All our mushrooms and toadstools are developed as fruiting bodies from a vast mycelial network--usually in moist warm seasons--as spring or fall. Each of these mushrooms indicate a relatively immense network or mass of hyphae in the humus.

One other association of importance is one involving a fungus and an alga (one of the green, microscopic plants). These two plants live together. They form greenish crusts on rocks, moss-like cushions on soil, and in many ways appear to be separate and distinct plants. These are the lichens. They are very important in colonizing bare rock.

Soil Algae

Algae are microscopic plants--single-celled or in threads or plates or clumps--that contain chlorophyll. Most of them must have light in order to manufacture food, which chlorophyll enables them to do. There are a few, though, that can make their food from carbon that is present in dead organisms--just as fungi do.

Algae are to be found in the top few inches of soil most commonly. Their need for sunlight might seem to explain this. But scientists keep finding some several feet down--where there is certainly no light.

Three types of algae are numerous in soil. They are called greens, blue-greens, and diatoms. The blue-greens are thought to be most closely related to fungi or to bacteria.

It is the algae which along with certain bacteria are able to use carbon dioxide and water to form sugars. This is photosynthesis--one of the most important processes in the living world.

Besides this, some of the blue-greens can use nitrogen from the air to produce various nitrogen compounds that can be used by them and by other organisms to form protein and ultimately, protoplasm, the living substance itself.

Exactly what role algae play in the soil and how important they are is simply not known. They produce at least some of the free oxygen required for the growth of fungi. Some of them--notably the blue-greens--fix atmospheric nitrogen. Blue-greens make it possible to grow rice in rice paddys of the tropics without adding nitrogen fertilizer. This is an important matter indeed in the tropics. Many other microbes feed on algae and thus algae play a part in soil biology. It is known that blue-green algae play a very important part in colonizing bare or eroded soil.

The diatoms and most blue-greens are mobile--that is they can move, even if very slowly. Most of the greens do not move.

We know less about these plants than about any other group of soil organisms.

Protozoa

Protozoa are primitive, single-celled animals. All of them are mobile, that is, they can move about. Some do it with a few long whips or flagellae, some by rows of short hairs or cilia that paddle the organism like oars in a racing shell, and some move by means of pseudopodia. This last type of locomotion means that the organism extends itself, then flows into the extension. None can move except in water, thus they move only in the film of water surrounding the soil particles, or in porous areas filled with water.

Protozoa feed on bacteria or on materials dissolved or in particle form in soil water. Some forms also feed on algae. Most of them reproduce by simply dividing in two. Some may conjugate--that is, two of them join; there is an intermingling of protoplasm and two new individuals eventually emerge. If food gets short or the soil drys out, the protoplasm forms a cyst--which is simply the animal inside a tough outer protective case. These cysts can withstand difficult conditions and may persist in the soil through long periods of drought. Once conditions are better, the animal comes out again and resumes normal living.

Generally some 10 to 100 thousand protozoans are found in a gram of soil. Counts made of bacteria are usually several times greater. Volume for volume, protozoa weigh more than the bacteria, even so. More flagellates are present than the others. Ciliated forms are the most uncommon. Adequate moisture must be present if protozoans are to thrive.

We're really not sure of the function of the protozoans. Mostly scientists think they regulate the populations of bacteria, but this is still not certain. The fact that we do not know the part they play in the soil population does not mean they are unimportant. It means we are ignorant.

Nematodes

Of all the animal life in the soil, the nematodes or eelworms seem to have no particularly beneficial effect on anything. There are between one and two thousand species or perhaps more of these thread-like organisms in the soil. They are just at the limit of visibility, and transparent. They move by crawling or swimming with eel-like movements in the film of water surrounding the soil particles. They may number from 1 to 20 million per square yard, weighing up to 180 pounds per acre.

These eelworms seem to fall into two general groups. Either they are parasites or they are predators. The parasites work on other animals, on the higher plants, and on man himself. Trichinosis and hookworm are caused in humans by nematodes. Not all these parasites live in the soil, but those that do cost us millions of dollars in damage to all sorts of crop plants. These creatures, the parasitic ones that is, attack the roots of potatoes, tomatoes, and a host of trees, shrubs, and other plants. They cause what are called root-knots,--swellings in the roots of the plants that are parasitized--that take food from the plant and thus reduce its growth.

The predators are of a different breed. They prey on algae in the soil, on fungi, bacteria, actinomycetes, protozoa, on other nematodes, and on other animals. As far as we know, they do not contribute anything to the processes of decay. Nor do they affect the physical properties of soils. They simply eat whatever living plants or animals they run across.

They are abundant in the soil and are found everywhere. They require water to be active. When the soil dries, the nematodes form cysts--the living organism or egg inside a tough skin. These cysts resist dryness, high and low temperatures (as low as - 271° centigrade) and even radiation a thousand times greater than that required to kill human beings.

Although the parasitic forms that cause root-knots have been studied a great deal, for obvious reasons, we really know next to nothing about these tiny worms. They most certainly play a part in the jungle of life in the soil, but what that part is we have still to discover.

The Macrofauna

All the living organisms in the soil that we don't have to have a microscope to see, have been classed as the macrofauna, i.e., the bigger animals. All these organisms are animals, and all of them affect the soil mechanically. Some do this by burrowing or digging their way through the soil. Others, the smaller ones, enlarge the soil pores as they move through. Others move the soil particles to one side as they burrow. Still others move the soil with their digging, and some build mounds or heaps of soil in which they live.

These larger soil animals affect the soil in a number of ways. Their burrowings and diggings loosen the soil and this helps in the drainage of excess water. The same actions help to aerate or introduce air into the soil. They grind up the plant and animal material they eat and release it as droppings or a manure the micro-organisms can readily attack. And, they mix this material with the soil in which they are digging; this is equivalent to cultivation. Agriculturists know that all these effects are valuable in the soil in that they enable the roots of higher plants to penetrate and use the nutrients more readily.

There are many kinds of animals in the macrofauna. Some of them are familiar enough to most people. These include such animals as foxes, rabbits, ground hogs and armadilloes, moles, prairie dogs, gophers and other burrowing rodents, earthworms, slugs and snails, spiders, mites, centipedes, millipedes, ants, termites and crayfish. But there are many others that may be only names to most of us. Among these are springtails, woodlice or pillbugs, enchytraeid worms (smaller relatives of the earthworm), and the immature or larval forms of hundreds or thousands of insects. Merely names perhaps, but important creatures nonetheless in one way or another in soils.

Work of the Macrofauna

In many studies, counts of the macrofauna (excluding the bigger animals) have ranged from 3 million to 760 million per acre in the surface six inches. Although the numbers are quite large, the work of most of the different kinds of animals has not been measured seperately. Earthworms have possibly received most attention. From 1 to 3 million of these creatures per acre have been found where they occur, weighing in total between 1,500 and 2,000 pounds.

Where earthworms are common, they move great quantities of soil. Charles Darwin was first to call attention to this. He estimated earthworms on pastures near his home to be bringing up about 20 tons of soil per acre per year. In 30 years this would amount to a new layer of soil 7 inches deep. These figures are for worms that make little mounds or casts at the surface of the soil. Some rough estimates suggest that upwards of 36 tons per year may be passed through the worms.

Ants have been shown to transfer about 30 tons of soil per acre per year. The termites of the tropics are important in the decay of plant materials in the tropics. They build mounds up to 25 feet high and 40 to 60 feet in diameter. More than 5,000 tons of soil per acre may be moved in building these huge structures over a period of years.

Some of the larger animals have considerable effects on the soil also. For example, in Yosemite one study showed that pocket gophers brought up 3.6 tons of earth per square mile. These animals are thought to be the "chief natural cultivators" of the soil in some of our dry western country. Here, they take the place of moles and earthworms characteristic of the eastern states.

Decay and Its Value

The chemical processes going on in the soil are almost unbelievably complex. The variety of chemical compounds involved is staggering. Many, -- probably most -- of the processes are not understood at all. What each of the thousands of species of micro-organisms is doing in the soil it inhabits is for the most part uncertain.

Certain gross processes are known to take place, and one of the most importan of these is decay.

When plants or animals die, their bodies are returned to the soil where they decay. If this did not take place, the world would soon be filled with the dead bodies of plants and animals. These dead bodies would eventually lock up all the chemicals needed by living organisms. Without decay, in other words, life in the world would finally come to a halt -- for a lack of the chemical materials needed for life and growth of new organisms.

However distasteful decay may seem to us, it is essential to the continuation of life. Decay is as natural as anything else occurring in our environment. It may be unpleasant, odoriferous, even nauseating, but unless it took place living things would die out -- including man. It is the micro-organisms of the earth that we have to thank for the cleanup part of the great cycle of life.

In the processes of decay, many chemical materials are changed. In a general way, complex materials that once formed living organisms are broken down into simpler substances. In certain forms, these simpler compounds can be taken up and used by the higher plants (the trees, shrubs, grasses, and other vegetation). The higher plants use the simpler compounds to form their proteins and ultimately their protoplasm or living substance. This is a matter of key importance in the world. As we have noted, all animals and human beings depend entirely on plants, either directly or indirectly, for food. Thus, unless the micro-organisms make the necessary simpler chemicals available to the higher plants, we would find life and growth impossible.

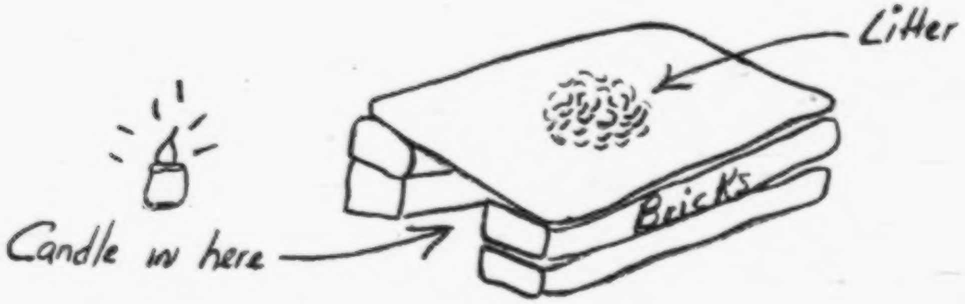
An important example of the simpler chemicals is carbon dioxide produced in the course of the decay process. There are measurements showing that about 2000 pounds of carbon dioxide per acre are released from the soil into the atmosphere each day, during the four warm months of the year. As we have already seen, the amount of carbon dioxide in our atmosphere is relatively small in comparison to the other gases. Enormous quantities of it are needed -- and used -- by the earth's vegetation in photosynthesis. Sooner or later though, the carbon dioxide used up by plants is returned to the atmosphere by the processes of decay. Thus the great cycle is completed.

Problem: Living Organisms in Soils   Unit 6

Collect a sample (a convenient handful) of partially decomposed leaf litter in a wooded area. Brush away dried leaves and twigs, take a handful of the material immediately exposed. Place in a cellophane bag and take it home.

Get an old frying pan, or cookie tin, or flat piece of tin sheeting, or piece of asbestos sheeting, about 8-12 inches on each edge. Put a piece of white paper of the same size and shape on the tin or asbestos. Support this on two sides with a couple of bricks.

Put your litter sample on the white paper in a neat pile about an inch deep and 3-4 inches across. Now put a lighted candle in the center underneath so that the flame just reaches the tin or asbestos: thus



Now watch what happens. Count the number of macro-organisms that come out and try to identify what they are.

Using whatever you learn from this, plus reading, make a brief report on macro-organisms in the soil.

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name:__________________________

Address:________________________

____

Working Title:___________________

Unit No. & Title:_________________

____

Date Submitted:__________________

Hours Spent on this lesson:_______

(Block below for instructor use)

Date Received:________________

Date Returned:________________

Comments:

____
(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 7

WATER AND ITS POLLUTION

Unit No. 7

Water and Its Pollution

Reading Assignment:

Odum, Chapter 11 (p. 295 - 323)
(p. 432 - 440)

Sediment Yield of Major Rivers of the World by Holeman
Wagner, Chapters 6, 7, and 8.
Brubaker, pp. 138-148

Assignment:

Find out and report on the domestic water supply system of your area. Do the same for the sewage disposal system.

When was each set up and by whom?
What capacity do they have?
What problems are being encountered?
How effective is each now? For the immediate future (5-10 years)?

VOL. 4, NO. 4 WATER RESOURCES RESEARCH AUGUST 1968

The Sediment Yield of Major Rivers of the World

JOHN N. HOLEMAN

Engineering Division, Soil Conservation Service
U. S. Department of Agriculture, Hyattsville, Maryland 20782

Abstract. The amount of suspended sediment transported by rivers to the seas each year is tabulated. The major rivers are ranked in order of tons of sediment transported per year and drainage area and water discharge data are included. The rivers are listed by continents in subsequent tables with data on drainage area, annual sediment yields in tons, sediment production rates in tons per square mile per year, the years of sediment measurement, and the sources of data. This sample represents more than one-third of the land contributing water-borne sediment to the seas and, if representative, indicates an annual world sediment yield of 20 billion (20×10^9) tons. The data suggest that Africa, Europe, and Australia have very low sediment yields (<120 tons per square mile per year), South America's rate is low, North America's is moderate, and Asia's is high to the degree of yielding up to 80% of the sediment reaching the oceans annually. (Key words: Data; erosion; runoff; sediment; world)

INTRODUCTION

Knowledge of the amount of sediment transported by the various rivers of the world is important for many reasons. For example, reservoirs should be designed with enough space to store the sediment expected to accumulate in them and yet retain full effectiveness during their design life, and sediment yield is an indication of the rate of erosion in the drainage basin. A summation of sediment yields by basins may indicate a regional, continental, and even an approximate world rate.

The amount of sediment transported by water to ocean level has been estimated by a number of people. These estimates have covered a rather wide range. For example, *Fournier* [1960] calculated more than 64×10^9 (64 billion) tons a year. The estimate of *Lopatin* [1952] was about 14×10^9 short tons annually. The data compiled here represent more than a third of the land contributing to the sea. Direct extrapolation of these data by continents gives a world total sediment yield to the marine environment of 20.2×10^9 tons per year.

The validity of some of the data is questionable because of short records and variability of sediment sampling methods. In addition, some of the data may include estimates of sediment transported as bedload, whereas most only include suspended loads. This compilation is not a complete listing of all of the major rivers discharging to the sea whose sediment load has been measured; however, it does include the major rivers (excepting some in the United States) with published data that the writer could locate at this time.

The data were reported in many different forms, such as cubic meters per year, metric tons per square kilometer per year, and kilograms per second, and some large area denudation rates were given in feet per thousand years and millimeters per year. The various weights were converted into short tons (2000 lbs) and areas into square miles. For the conversion of volume of rock eroded into weight, the average specific gravity of the rock was assumed to be 2.65.

GENERAL

The Earth's surface is nearly 200 million square miles (actually 196.9). Of this, 71% is water. Land makes up the remaining area of 57.5 million [redacted] square miles. Of this, about 5 million are in Antarctica, and about 13.2 million square miles are closed basins and deserts contributing no runoff. According to *Livingstone* [1963], this leaves 39.2 million square miles contributing runoff and waterborne sediment to the seas.

Strahler [1963, p. 264] presents a world map of average annual precipitation, and *Putnam* [1964] estimated the average annual rainfall on land to be 24,000 cubic miles a year (between 26 and 27 inches). *Langbein and Schumm* [1958] found that the maximum sediment yield in the United States occurs when annual effective precipitation is between 10 and 14 inches. The sediment yield dropped sharply as annual rainfall decreased from 10 inches because of the deficiency of runoff. On the other hand, sediment yield decreased generally with rainfall above 14 inches, because the increased rainfall produced a greater density of vegetative cover and therefore less erosion.

This generalization may or may not apply to other environments of the world, but the relation between rainfall and vegetative cover seems universal. A world map showing the distribution of types of vegetation is in the 1941 Yearbook of Agriculture, *Climate and Man* [*U. S. Dept. Agr.*, 1941]. The vegetation reflects rather closely the annual rainfall patterns. The rates of runoff are also closely tied in with precipitation. In 1960, Durum and others estimated the annual worldwide runoff to be 40 million cfs, or approximately 1 cubic foot per second per square mile (csm). Recently, with additional data, the figure has been refined downward to 0.82 csm (W. H. Durum, personal communication, 1968). This is 11.1 inches of worldwide runoff.

A summary of sediment yields on a worldwide basis was not available, and this, in large part, is what prompted preparing this compilation. Of the 16 rivers having drainage areas greater than 400,000 square miles, no sediment data were located for the Lena and Amur in northeastern Asia, the Mackenzie and Nelson in Canada, and the Zambezi in southeast Africa. The Nelson River flows from Lake Winnipeg to the Hudson Bay. Sediment data are included for the two principal tributaries of Lake Winnipeg, the Red and Saskatchewan rivers. The Murray River in Australia has about the same drainage area as the Nelson, and sediment yield is estimated for it (see page 741). Table 1 lists 16 rivers that transport more than 100 million tons of sediment to the sea annually. To facilitate comparisons of the sediment production rates of the world's river basins, the following arbitrary but convenient limits were used: those exceeding 500 tons/sq mi/yr as high; those between 200 and 500 as moderate; and those under 200 as low.

TABLE 1. Selected Rivers of the World Ranked by Sediment Yield ($>10^8$ tons/yr)

Name	Location	Total Drainage Area,* 10^3 sq mi	Average Annual Suspended Load		Average Discharge at Mouth,* 10^3 cfs
			(thousand tons)	(tons/sq mi)	
1. Yellow	China	260	2,080,000	7,540	53
2. Ganges	India	369‡	1,600,000	4,000	415
3. Bramaputra	East Pakistan	257‡	800,000	3,700	430
4. Yangtze	China	750	550,000	1,400	770
5. Indus	West Pakistan	374‡	480,000	1,300	196
6. Ching (Yellow trib.)	China	22†	450,000	20,500	2
7. Amazon	Brazil	2,230	400,000	170	6,400
8. Mississippi	USA	1,244	344,000	280	630
9. Irrawaddy	Burma	166	330,000	2,340	479
10. Missouri (Miss. trib.)	USA, Missouri	529	240,000	450	69
11. Lo (Yellow trib.)	China	10†	210,000	20,200	...
12. Kosi (Ganges trib.)	India	24‡	190,000	7,980	64‡
13. Mekong	Thailand	307‡	187,000	1,240	390
14. Colorado	USA	246§	149,000	1,080	5.5§
15. Red	North Viet Nam	46‡	143,000	3,090	138‡
16. Nile	Egypt	1,150	122,000	100	100

Incomplete, as data for many rivers are lacking. For sources consult Tables 2, 3, 4, and 5.

* Data in these two columns are from AGI Data Sheet No. 32 (rev. 1964), unless otherwise noted.

† U. N. 1953.

‡ U. N. 1965.

§ *Durum et al.*, 1960.

TABLE 2. Suspended Sediment Yield of Selected Rivers, North America

River	Location	Drainage Area, sq. mi.	Average Annual Suspended Load (10³ tons)	Average Annual Suspended Load (tons/sq mi)	Average Water Discharge at Mouth, 10³ cfs	Period of Sediment Record	Source
Mississippi	Baton Rouge, Louisiana†		262,487			10/49-9/66	Hobbs, B. L. (personal communication, 1968)
Atchafalaya	Simmesport, Louisiana		121,400			10/51-9/65	Hobbs, B. L. (personal communication, 1968)
Mississippi	(sum of two above for 14 yrs.)	1,244,000	344,000	277	630‡	10/51-9/65	Hobbs, B. L. (personal communication, 1968)
Missouri*	Hermann, Missouri	528,200	239,562	454	69.3‡	1949-54	Hobbs, B. L. (personal communication, 1968)
St. Lawrence	mouth, Canada	498,000	4,000	8	500‡	...	*Corbel* [1959]
Colorado	Grand Canyon, Arizona	137,800	149,000	1,082	5.5	10/25-9/57	*Judson and Ritter* [1964]
Saskatchewan	The Pas, Canada	125,064	4,600	37	80§	1954-60; 62-64	*IASH* [1967]
Red	Lockport, Canada	110,782	1,770	16	80§	1956-58; 61-64	*IASH* [1967]
Snake	Central Ferry, Washington	103,500	13,100	127	48.6‡	4/50-7/52	*Judson and Ritter* [1964]
Columbia	Pasco, Washington	102,600	10,300	100	256‡	6/50-7/52	*Judson and Ritter* [1964]
Ohio*	Cincinnati, Ohio	76,580	15,000	196	258.1¶	10/41-9/42	Hobbs, B. L. (personal communication, 1968)
Yellowstone*	Glendive, Montana	66,880	30,300	455	...	1929-31	*Fournier* [1960]
Brazos	Richmond, Texas	34,800	34,800	1,000	5.2‖	1924-1950	*Fournier* [1960]
Rio Grande	San Acacia, New Mexico	26,770	9,420	352	2.7‖	10/47-9/56	*Judson and Ritter* [1964]
Alabama	Claiborne, Alabama	22,000	2,130	97	31.9‡	10/52-9/60	*Judson and Ritter* [1964]
Potomac	mouth, Maryland & Virginia	14,600	2,509	170	11.1**	...	*Sedimentation* [1967]
San Joaquin	Vernalis, California	14,010	347	25	4.7††	10/56-9/60	*Judson and Ritter* [1964]
Rio San Juan	Santa Rosalia, Mexico	12,000	5,340	445	0.3‖	1934-1941	*Fournier* [1960]
Delaware	Trenton, New Jersey	6,780	998	147	20.1‡	10/49-9/57	*Judson and Ritter* [1964]
Sabine	Logansport, Louisiana	4,860	730	150	8.8‖	1932-1950	*Fournier* [1960]
Pecos	Puerto de Luna, New Mexico	3,970	2,720	685	0.6‖	10/48-9/57	*Judson and Ritter* [1964]
Eel	Scotia, California	3,113	18,200	5,846	7.0††	10/57-9/60	*Judson and Ritter* [1964]
	Total (without tributaries)	2,464,649	603,955	Average 245			

*** Tributary to a listed river.**
† Sampling at Red River Landing after Jan. 1, 1958.
‡ AGI Data Sheet #32 (rev. 1964).
§ AGI #32, mouth of Nelson River.
‖ U. S. Geol. Surv. Water-Supply Paper 1732.
¶ U. S. Geol. Surv. Water-Supply Paper 1725.
**** U. S. Geol. Surv. Water-Supply Paper 1722.**
†† U. S. Geol. Surv. Water-Supply Paper 1735.

NORTH AMERICA

North America is the continent with the most data collected on sediment transported by water. Most of the data are from the United States and are derived from secondary sources as indicated (Table 2). The original data used by these sources were collected mostly by the U. S. Geological Survey and the U. S. Corps of Engineers.

The rivers are listed in descending order of drainage area. The Mississippi since 1949 has transported an average of 262 million tons a year past Red River Landing and Baton Rouge, Louisiana. This average is based on the U. S. Corps of Engineers measurements for 1949–1966. Before 1952, an annual load of 500 million tons at this location was not unusual; since then, no more than 325 million tons have been measured in any one water year. Soil conservation practices, streambank stabilization measures, and new reservoirs have been the major factors in this reduced sediment transport.

Brown [1950] reported that the Missouri River at Yankton, South Dakota, carried an average of 134 million tons a year. This figure was based on nine years of record. In 1953 storage began at Ft. Randall and Garrison Dams, 82 and 615 river miles upstream from Yankton, respectively. In June 1955, Gavins Point Dam, only a few miles upstream from Yankton, was closed. The effect of these three dams upstream can be noted in the sharp decline of the suspended load to an annual average (1955–1963) of 2,363,000 tons per year (D. C. Bondurant, Corps of Engineers, personal communication, 1968).

The St. Lawrence has a large drainage area, but much of it consists of the Great Lakes and, as one might expect, the St. Lawrence carries a very small amount of sediment. The Colorado discharges a large load, formerly much more than it does now. The 149 million tons (Table 2) is a 32-year average.

Additional rivers with decreasing drainage areas and sediment yields are listed. There is only one river in Mexico listed, and for Canada, besides the St. Lawrence, only the Saskatchewan and the Red are listed. Sediment in these two rivers in south central Canada was measured upstream from their debouchment at Lake Winnipeg. The average annual sediment load was measured at 37 and 16 tons per square mile, respectively. The average sediment load for the rivers listed in Table 2 is 283 tons per square mile per year; after deleting the rivers that are tributaries, the average for North America becomes 245 tons per square mile per year.

SOUTH AMERICA

The continental divide in South America, or crest of the Andes mountains, is near the Pacific Ocean. The rain falling on the eastern slopes of the Andes has to travel down the Amazon about 3000 miles to the Atlantic Ocean. The Amazon has the largest drainage area of any river in the world and by far the largest water discharge. Because of the heavy rainfall on the large basin, the Amazon is believed to discharge anywhere from 11% [*Oltman*, 1964] to 18% [*Davis*, 1964] of the world's total annual volume of water discharged into the oceans. On the other hand, it transports only about 2% of the sediment reaching the oceans annually. According to *Gibbs* [1967], 82% of the suspended sediment reaching the mouth of the Amazon comes from the Andes mountains and highlands, only 12% of the drainage area; and about 6% of the total sediment discharge is bedload.

There are other very large rivers in South America. The Orinoco discharges the third largest volume of water in the world, exceeded only by the Amazon and Congo, but its sediment yield is moderate (Table 3). The Parana′ to the south ranks eighth in the world in both drainage area and water discharge, but sediment yield is low: only 100 tons per square mile. An estimate of the sediment yield for South America is 160 tons per square mile (Table 3).

AFRICA

On the basis of this sample of five rivers, Africa has less than one-half the sediment production rate of South America: about 70 tons per square mile. The rate of the Medjerdah in Tunisia is high, the Cheliff in Algeria is moderate, the Nile is low, and the Niger and Congo are remarkably low (see Table 3).

Africa has four main rivers, each discharging to one of the four points of the compass: the Nile to the north, the Niger to the south, the Zambezi to the east, and the Congo to the west. The table indicates low sediment yields in central Africa. Although evidence of excessive ero-

TABLE 3. Suspended Sediment Yields of Selected Rivers
South America—Africa—Australia

River	Location	Drainage Area, sq. mi.	Average Annual Suspended Load (10³ tons)	Average Annual Suspended Load (tons/sq mi)	Average Water Discharge at Mouth,† 10³ cfs	Period of Sediment Record	Source
South America							
1 Amazon	mouth, Brazil	2,368,000	400,000	170	6,400		Ames, F. C. (personal communication, 1967)
2 Parana	mouth, Argentina	±890,000	90,000	100	526		*Corbel* [1959]
3 Orinoco	mouth, Venezuela	366,700	95,340	260	800		*Van Andel* [1967]
4 Uruguay	Concordia, Argentina	150,000	15,000	100	140		*Babb* [1893]
5 Negro*	Primera Angustura, Argentina	36,670	1,487	405	36	1935–1965	*IASH* [1967]
6 Caroni*	at Orinoco, Venezuela	±35,000	52,500	1,500			Koelzer, V. A. (personal communication, 1967)
7 Colorado	Pichi Mahuida, Argentina	9,000	7,600	880		1938–1964	*IASH* [1967]
	Total (less tributary)	3,820,370	609,427	Average 160			
Africa							
1 Congo	mouth, Congo	1,550,000	71,300	46	1,400		*Corbel* [1959]
2 Nile	delta, Egypt	1,150,000	121,854	100	100	1958–1964	Simons, D. B. (personal communication, 1967)
3 Niger	Baro, Nigeria	430,000	4,960	12	215		*Dekker* [1961]
4 Cheliff	mouth, Algeria	8,600	3,400	395		16 years	*Tixeront* [1960]
5 Medjerdah	mouth, Tunisia	8,080	14,750	1,825		5 years	*Tixeront* [1960]
	Total	3,146,680	216,264	Average 70			
Australia, et al.							
30 streams	Eastern Australia			85		2 years	*Douglas* [1967]
Murray-Darling	mouth, Australia	414,000	35,190				
Waipaoa	Kanakanaia, New Zealand	610	12,160	19,930	13	1960–1964	*IASH* [1967]
	Total	414,610	47,350	Average 115			

* Tributary to listed river.
† AGI Data Sheet No. 32 (rev. 1964).
‡ Estimate based on the 85 tons/sq. mi mentioned in text.

sion in South Africa exists, no quantitative data were located.

AUSTRALIA

Sediment yield data for Australia are very limited. According to Fournier [1960], eastern Australia appears to average about 850 tons per square mile. *Douglas* [1967] disputed this rate. He has observed the sediment load in 30 rivers in eastern Australia (New South Wales and Queensland) and believes that Fournier's figure is too high by a whole order of magnitude. Therefore, a figure of 85 tons per square mile may be more in order, although it is only an estimate. The vast central part of this island continent is a desert.

EUROPE

Europe has none of the 16 major rivers of the world no matter whether they are ranked by drainage, water discharge, or sediment yield (Table 1). In terms of drainage area, the Volga, which empties into the Caspian Sea, ranks seventeenth. It carries a low suspended sediment load. The second largest is the Danube, flowing from southwestern Germany eastward into the Black Sea. Its sediment load is also low (Table 4).

The Rhine carries a heavy load of sediment as it enters Lake Constance in Switzerland, but by the time it reaches the flatlands of Holland it carries little sediment. The Po, the Tiber, and the Arno in Italy carry relatively high amounts of sediment, but generally erosion is not a big problem in Europe. This is because rainfall is distributed well throughout the year, and low-intensity, gentle rains are typical. The average sediment production rate is about 90 tons per square mile based on these data.

ASIA

The largest continent, Asia, also produces by far the most sediment reaching the sea (Table 5). According to a United Nations publication of 1953, *The Sediment Problem* [*United Nations*, 1953], the Yellow River of China carries more than 2×10^9 short tons of sediment to the Yellow Sea each year on the average. The principal source is the yellow loess of north central China, giving the river and sea its color and name. The Yangtze River to the south of the Yellow River also flows from west to east. Although the Yangtze drains a much larger area than the Yellow River, it transports approximately a fourth of the amount of sediment. The Lo and Ching rivers are tributaries to the Yellow and carry nearly three times as much sediment per square mile as any of the other rivers of the world with equal or larger drainage areas listed here (20 thousand tons per square mile). At times, flows in the Yellow River have been reported to be 40% sediment by weight; that is, 400,000 ppm [*Todd and Eliassen*, 1938]. The Yellow River carries the largest amount of sediment of any river in the world.

The Ganges River in India is the second largest carrier of sediment, discharging more than $1\frac{1}{2} \times 10^9$ tons of sediment into the Bay of Bengal each year. The Ganges arises along the southwest side of the Himalaya Mountains and flows south of them roughly parallel to their crest. The runoff from most of the south side of this highest mountain range in the world flows into the Ganges. This area is subject to intense erosion because of the high relief and the monsoon climate. Some of the maximum annual rainfalls and most intense storms of the world have occurred in the foothills of the Himalayas. As an example, at Cherrapunji, India, in the Khasi Hills, 241 inches of rain fell in the month of August 1841, 40.8 inches of which fell in one day. The average annual rainfall at Cherrapunji is 426 inches [*U. S. Dept. Agr.*, 1941, p. 664]. The Kosi, tributary to the Ganges, alone transports on the average 190 million tons of sediment a year.

The Bramaputra River originates on the north side of the Himalayas in Tibet. It flows eastward and also roughly parallels the trend of the mountains. On the eastern flank of the Himalayas the Bramaputra breaks through to the south, then reverses directions and flows west along the southeastern side of the mountains. It empties into the Bay of Bengal, forming a joint delta with the Ganges. These two rivers are thought to rank as number 2 and 3 among the world's rivers in the amount of sediment discharged. The Indus River in West Pakistan transports almost as much sediment as the Bramaputra.

Eleven of the 16 rivers in Table 1 with sediment yields $>10^8$ tons are in southern Asia. Undoubtedly, as the store of data increases,

TABLE 4. Suspended Sediment Yields of Selected Rivers
Europe

River	Location	Drainage Area, sq. mi.	Average Annual Suspended Load (10^3 tons)	Average Annual Suspended Load (tons/sq mi)	Average Water Discharge at Mouth, 10^3 cfs	Period of Sediment Record	Source
Volga	Dubovka, USSR	521,490	20,770	40	283‡	1934, 35, 38–40	*Lopatin*, 1952
Danube	mouth, USSR	315,000	21,420	68	218‡		*Babb*, 1893; *Corbel*, 1959
Dnepr	Verkhnedneprovsk, USSR	167,520	1,210	7	194‡	1938–39	*Lopatin*, 1952
Don* (Volga trib.)	Razdorskaya, USSR	146,020	5,360	37		1932–40, 46, 47	*Lopatin*, 1952
Ural	Topolinski, USSR	74,790	1,760	24		1936–41, 47	*Lopatin*, 1952
Vistula	Tczew, Poland	74,560	1,690	23	38‡	1946–53	*Jarocki*, 1963 (p. 80)
Tisza*	at Danube River, Hungary	60,310	11,040	180		not cited	*Fournier*, 1960
Rhine	mouth, Holland	56,000	504	9	78‡	not cited	*Corbel*, 1959
Rhine*	Lake Constance, Switzerland	4,600	9,632†	2,094†		not cited	*Corbel*, 1959
Loire	Nantes, France	46,740	467	10	30§	not cited	*Corbel*, 1959
Oder	Gozdowice, Poland	42,230	147	4		1961–64	*IASH*, 1967
Po	Pontelagoscuro, Italy	20,960	16,770	800	51‡	1956–62	*IASH*, 1967
Seine	Paris, France	17,140	1,220†	71†		pre 1865	*Corbel*, 1959
Tiber	Rome, Italy	6,390	6,420	1,005		1933–46, 49–63	*IASH*, 1967
Drin	Can Deje, Albania	4,770	16,220	3,400		1960–63	*IASH*, 1967
Garonne	Toulouse, France	3,860	2,760	715	24§	1839–46	*Fournier*, 1960
Inn*	Reisach, West Germany	3,767	3,515	933		1953–1960	*IASH*, 1967
Arno	San Giovanni alla Vena, Italy	3,160	2,430	770		1936–42; 54–64	*IASH*, 1967
Semani	Urae Kucit, Albania	2,040	24,190	11,844		1961–63	*IASH*, 1967
Simento	Giarretta, Sicily	707	3,960	5,605		1936–42; 57–63	*IASH*, 1967; *Gezzolo and Bassi*, 1930
	Total (less tributaries)	1,357,357	121,938	Average 90			

* Tributary to a listed river.
† Includes bed load.
‡ AGI Data Sheet No. 32 (rev. 1964).
§ Durum, W. H. (personal communication, 1968).

TABLE 5. Suspended Sediment Yields of Selected Rivers
Asia

River	Location	Drainage Area, sq. mi.	Average Annual Suspended Load (10^3 tons)	Average Annual Suspended Load (tons/sq mi)	Average Water Discharge at Mouth, 10^3 cfs	Period of Sediment Record	Source
1. Yenisei	Igarka, USSR	954,200	11,600	12	614†	1942, 43	*Lopatin* [1952]
2. Ob	Salekhard, USSR	945,300	15,700	17	441†	1938–44	*Lopatin* [1952]
3. Ganges	delta, East Pakistan	409,200	1,600,000	4,000	498‡	1874–1879	*Fournier* [1960]
4. Yangtze	Chikiang, China	395,650	552,000	1,400	770†		*U. N.* [1953]
5. Indus	Kotri, West Pakistan	370,000	481,000	1,300	239‡	1902–25	*Fournier* [1960]
6. Indus*	Kalabagh, West Pakistan	117,700	751,000	6,370			*U. N.* [1965]
7. Yellow	Shenhsien, China	276,000	2,083,000	7,545	53‡	1934–42	*U. N.* [1953]
8. Bramaputra	delta, East Pakistan	216,000	800,000	3,700	706		*U. N.* [1965]
9. Mekong	Mukdaham, Thailand	151,000	187,000	1,240	530		*U. N.* [1965]
10. Irrawaddy	Prome, Burma	141,700	331,000	2,340	479†		*U. N.* [1953]
11. Pearl-West	Wuchow, China	120,800	30,800	250	277		*U. N.* [1953]
12. Mahanadi	Naraj, India	51,000	67,800	1,330	101		*U. N.* [1953]
13. Euphrates	Tabqa, Syria	46,570	4,750	100	51§	1962–64	*IASH* [1967]
14. Red	Hanoi, North Viet Nam	46,300	143,000	3,080	138		*U. N.* [1965]
15. Chao Phya	Nakornsawan, Thailand	41,100	12,490	300		1956–63	*IASH* [1967]
16. Kabul*	Nowshera, West Pakistan	34,880	26,000	745	24‡	1961, 1962	*Koelzer* [1967]
17. Tigris	Bagdad, Iraq	30,800	57,600	1,870	51§	1918, 1919	*Fournier* [1960]
18. Kosi*	Chatra, India	23,800	190,000	7,980	64		*U. N.* [1965]
19. Ching*	Changchiashan, China	22,000	450,000	20,500	2	1932–45	*U. N.* [1953]
20. Chenab*	Alexandria Bridge, W. Pakistan	12,560	55,000	4,380		1961, 1962	*Koelzer* [1967]
21. Lo*	Chuantou, China	10,400	210,000	20,200		1934–45	*U. N.* [1953]
22. Damodar	Rhondia, India	7,680	31,300	4,050	11		*U. N.* [1953]
23. Ishikari	Ebestu, Japan	4,900	1,926	393		1960	*IASH* [1967]
24. Tone	Matsudo, Japan	4,630	3,160	778		1951	*IASH* [1967]
	Total (less tributaries)	4,212,830	6,414,576	Average 1,530			

* Tributary to a listed river.
† AGI Data Sheet No. 32 (rev. 1964).
‡ *U. N.* 1965.
§ Tigris, Euphrates, and Karun Rivers, *Geotimes*, March 1962.

there will be changes in this list. Southern Asia, however, will remain the principal contributor of sediment to the oceans.

Northern Asia, consisting of Siberia and Mongolia, has little sediment data available. Yet four of the world's largest rivers, in terms of drainage area, are in northern Asia. From west to east they are the Ob, the Yenisei, and the Lena, which flow north into the Arctic Ocean, and the Amur, which flows east to the Pacific. The best indication of sediment yield in this area is the report of *Lopatin* [1952] that the average annual denudation for the USSR is 0.027 mm. This is equivalent to 1.06 inches per 1000 years, or about 200 tons per square mile per year. The estimated annual rate of sediment reaching the oceans from Asia is 1530 tons per square mile (closed basins and deserts excluded).

SUMMARY

The measured and estimated sediment yield are summarized by continents in Table 6: Africa, Europe, and Australia appear very low, averaging 70, 90, and 115 tons per square mile each year, respectively; South America is low with 160 tons per square mile; North America is a moderate sediment producer with 245; and the high producer of sediment is Asia, with 1530 tons per square mile.

Table 6b shows the total sediment yield to the oceans as extrapolated directly from the above data. Using the total areas draining to the oceans and multiplying by the average rates ascertained, the total is 20.2×10^9 tons. Of this, 80% comes from Asia, which makes up one-quarter of the land area draining to the oceans. Table 7 compares this figure with some other world estimates.

To visualize better the 20.2 billion tons of sediment, consider it by volume rather than by weight. From reservoir sedimentation surveys of the United States, the volume-weight of submerged sediment deposits may be assumed

TABLE 6a. Summary of Measured Annual Sediment Yields of Rivers to Oceans (tributaries deleted)

Continent	Measured Drainage Area, Mi^2	Annual Suspended Sediment Discharge (Tons) (1000 tons)	(Tons/Mi^2)
North America	2,464,649	603,955	245
South America	3,820,370	609,427	160
Africa	3,146,680	216,284	70
Australia	414,610	47,350	115
Europe	1,357,357	121,938	90
Asia	4,212,830	6,414,576	1,530
Total	15,416,496	8,013,510	Average 520 tons/mi^2

TABLE 6b. Total Sediment Yield to Oceans Extrapolated from Above Data

Continent	Total Area Draining to Oceans,* Mi^2	Annual Suspended Sediment Discharge (Tons/Mi^2)	(10^9 Tons)
North America	8,000,000	245	1.96
South America	7,500,000	160	1.20
Africa	7,700,000	70	0.54
Australia	2,000,000	115	0.23
Europe	3,600,000	90	0.32
Asia	10,400,000	1,530	15.91
Total	39,200,000		20.16

Total suspended sediment discharge to oceans is about 20 billion tons a year.

* *Livingstone*, 1963.

TABLE 7. Comparison of Estimates of Sediment Reaching the Oceans Annually

Reference		Denudation or Sediment Yield		Equivalent*,
		various units	10^9 short tons	tons/sq mi
Fournier	1960	51.1 × 10^9 metric tons	= 64*	1630
Kuenen	1950	32.5 × 10^{12} kilograms	= 35.8	915
Gilluly	1955	12.0 km^3 of rock†	= 35.0	895
Pechinov	1959	0.09 mm/yr	= 26.7	680
Schumm	1963	0.25 ft/1000 yr‡	= 22.6	575
Holeman	1968	20.16 × 10^9 tons	= 20.2	520
Lopatin¶	1952	12.695 × 10^9 tons (metric)	= 14.0	355

* Adjusted to 39.2 milllion square miles contributing sediment to the oceans.
† A refinement of Kuenen's estimate.
‡ Based on drainage areas <1500 sq mi and effective precipitation of less than 40 inches per year.
¶ From *Jarocki* [1963, p. 8].

to average about 60 pounds per cubic foot, or about 1300 tons per acre-foot. On this basis the sediment reaching the sea each year is enough to cover France, Belgium, the Netherlands, Luxembourg, Switzerland, and Portugal with an inch of mud.

As a last observation about these sediment yield data, it is important to remember that these figures are a small per cent of the soil material that is moved each year. The Potomac River will serve as an illustration of this. The Potomac River Basin has been studied in greater detail than most of the areas included here. The Sedimentation and Erosion Sub-Task Force of the Federal Interdepartmental Task Force [*Sedimentation*, 1967] has estimated that about 2.5 million tons of sediment are discharged into the Potomac estuary annually. This group points out that gross erosion within the basin is over 50 million tons a year. In other words, only about 5% of the products of erosion in this watershed reach tidewater.

REFERENCES

Babb, C. C., The sediment of the Potomac River, *Science*, *21*, 342–343, 1893.

Brown, C. B., Sediment transportation, in *Engineering Hydraulics*, edited by H. Rouse, 769–857, John Wiley & Sons, Inc., 1950.

Corbel, J., Vitesse de l'erosion, *Z. Geomorphologie*, *3*, 1–28, 1959.

Davis, L. C., The Amazon's rate of flow, *Nat. History*, 73(6), 5–19, 1964.

Dekker, G., Sediment transport measurements and computations on the Niger, *Inter-African Conf. Hydrol., Publ. 66, London, Comm. Tech. Co-operation in Africa So. of Sahara*, 256–265, 1961.

Douglas, I., Man, vegetation, and the sediment yields of rivers, *Nature*, *215*, 925–928, August 26, 1967.

Durum, W. H, S. G. Heidel, and L. J. Tison, World-wide runoff of dissolved solids, *Intern. Assn. Sci. Hydrol., Publ. 51*, 618–628, 1960.

Fournier, F., *Climat et erosion*, Presses Universitaires de France, Paris, 1960.

Gazzolo, T., and G. Bassi, Contribution a l'etude des degre d'erosion des sals constituent les bassins versants des cours d'eau italiens, *Intern. Assn. Sci. Hydrol., Gen. Assembly, Helsinki*, 112–134, 1960.

Gibbs, R. J., The geochemistry of the Amazon River system: Part 1, *Geol. Soc. Am. Bull. 78*, 1203–1232, 1967.

Gilluly, J., Geologic contrasts between continents and ocean basins, *Geol. Soc. Am. Spec. Paper 62*, 7–18, 1955.

International Association of Scientific Hydrology, Transport total des sediments aux oceans, *IASH Bull. 12(3)*, 100–110, Sept. 1967.

Jarocki, W., A study of sediment (Badanie rumowiska) OTS 60-21273, English Transl., Warsaw, Poland, 254, 1963.

Judson, S., and D. F. Ritter, Rates of regional denudation in the U. S., *J. Geophys. Res.*, *69* (16), 3395–3401, 1964.

Kuenen, P. H., *Marine Geology*, John Wiley & Sons, New York, 568, 1950.

Langbein, W. B., and S. A. Schumm, Yield of sediment in relation to mean annual precipitation, *Trans. Am. Geophys. Union*, *39*(6), 1076–1084, 1958.

Livingstone, D. A., Chemical composition of rivers and lakes, in Data of Geochemistry, sixth ed., *U. S. Geol. Surv. Profess. Paper 440-G*, 64, 1963.

Oltman, R. E., F. O. Sternberg, F. C. Ames, and L. C. Davis, Amazon River Investigations, reconnaissance measurements of July 1963, *U. S. Geol. Surv. Circ. 486*, *15*, 1964.

Lopatin, G. V., Sediment deposits in the rivers of the USSR, *Izd. Geograficheskoi Literatury*, Moscow, 1952.

Pechinov, D., Water erosion and solids discharge (Vodna eroziya i to"rd ottok), *Priroda* (Sofia, Bulgaria), *8*(1), 49–52, 1959.

Putnam, W. C., *Geology*, Oxford University Press, New York, 480, 1964.

Schumm, S. A., The disparity between present rates of denudation and orogeny, *U. S. Geol. Surv. Profess. Paper 454-H*, Washington, D. C., 1963.

Sedimentation and Erosion Sub-Task Force of the Federal Interdepartmental Task Force, *Report on the Potomac*, Soil Conservation Service, U. S. Department of Agriculture, Hyattsville, Maryland, 31, 1967.

Strahler, A. N., *The Earth Sciences*, Harper & Row, New York, 681, 1963.

Tixeront, J., Debit solide des cours d'eau en Algerie et en Tunisie, *Intern. Assn. Sci. Hydrol., Gen. Assembly Helsinki*, 26–41, 1960.

Todd, O. J., and S. Eliassen, The Yellow River problem, *Proc. Am. Soc. Civil Engrs.*, *64*, 1921–1991, 1938.

United Nations, compendium of international rivers in the ECAFE region, *Proc. Sixth Reg. Conf. Water Res. Devel. in Asia, ECAFE*, New York, 1965.

United Nations, Soil erosion in various countries of the region, *The Sediment Problem*, ECAFE, Bangkok, 11–16, 1953.

United States Department of Agriculture, *Climate and Man*, 1941 Yearbook of Agriculture, U. S. Government Printing Office, Washington, D. C., 1248, 1941.

Van Andel, TJ. H., The Orinoco delta, *J. Sedimen. Petrol.*, *37*(2), June 1967.

(Manuscript received April 19, 1968;
revised May 8, 1968.)

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Washington, D. C. 20250

April 28, 1971

Advisory INF - 44

From: William R. Van Dersal
Deputy Administrator for Management

Re: "The Sediment Yield of Major Rivers of the World"

There is transmitted herewith a copy of John N. Holeman's paper on the sediment yield of major rivers of the world. This is a paper which brings together for the first time comparable data on the average annual suspended sediment loads of the major rivers of the United States as well as the rest of the world.

In view of the considerable importance of sediment and because there is a need for data of the sort included in Mr. Holeman's paper in discussions with the various groups, we thought you ought to have this publication for your files. Additional copies are not available after this widespread distribution.

William R. Van Dersal

Attachment

AO

Sediment

Sediment, the product of erosion, is our major pollutant. It does serious damage to land and water and to the constructions of man. At least four billion ~~tons of it~~ are washed into the tributary streams of the United States each year. About half of this reaches our lakes and rivers and one-fourth of this goes on to tidewater. It muddies our waters, it fills our reservoirs. It scars the land and reduces the productive capability of the soil whence it came. The average annual economic cost of sediment damage to the American people was roughly estimated by the Water Resource Council in 1968 to be in excess of 500 million dollars. Undoubtedly the loss of soil resources in creating this sediment far exceeds this amount.

In a few situations some benefits can be attributed to sediment. For example, induced deposition of sediment may create buffer zones to protect levees or other river bank structures. Alluvial soils result from sorting and deposition of some of the materials eroded upstream.

In addition to economic damage, the social costs of sediment are very high. It reduces the quality of our waters as habitat for fish and other aquatic life. It renders them unfit for water sports. It renders them unattractive. It carries phosphorous into our waters where its release may contribute to eutrophication. It carries into our waters pesticide chemical residues and other pollutants where they may be absorbed by fish and other aquatic organisms.

Sediment is a problem to varying degree in every area of the United States. About half the sediment originates on farm and forest land. The other half comes from roads and roadsides, stream banks, surface mines, and urbanization and other construction sites. In addition geological erosion on lands relatively undisturbed by man is a source of large amounts of sediment in certain areas of the country. The current USDA Conservation Needs Inventory provides the key to accelerated sediment damages by geographic areas. Nearly half the Nation's sediment originates in those 15 States west of the Mississippi and east of the Rockies.

Congress, the Executive Branch, state and local governments need to recognize and clearly state that sediment moving on to other lands and into streams, lakes and reservoirs is in fact a serious pollutant; and that at the national, state and local levels official action is needed to reduce the movement of soil as sediment.

Erosion and sediment control are needed on both rural and urban lands alike. Each year more than a million acres of land is converted from agricultural use to new houses, highways and roads, shopping centers, schools, airports, and the like. These changing acres are the source of much of the sediment that pollutes streams and rivers and fills lakes and reservoirs.

Studies show that erosion on land going into use for houses, shopping centers and highways is about 10 times greater than on cultivated farm land, 200 times greater than on grassland and 2,000 times greater than on land in timber. A cycle of 6 years from plan initiation to complete implementation is suggested. Congressional authorization would be required for much of the work.

There are more than 3,000 soil and water conservation districts covering 95 percent of the private lands in the 48 ~~continental~~ contiguous states. On the private lands of this nation the soil and water conservation district's major work is the control of erosion and sediment through proper land and water management. These conservation districts are legal subdivisions of state government, governed by local residents who know local conditions. The natural resource and related departments of the several states could effectively carry out the treatment of private lands in cooperation with USDA.

Working through soil and water conservation districts 2 million land users have conservation plans developed or underway to control erosion and sediment on their lands. Soil and water conservation districts need additional technical and financial assistance from public sources to accelerate the erosion and sediment control work on all lands within their boundaries. Acceleration of erosion and sediment control work of this nature would be of vast public benefit.

The Departments of Transportation, Defense, Housing and Urban Development and Interior have, or can develop, effective working relationships directly with landowners and managers or with developers and contractors to carry out effective erosion and sediment control methods.

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name:______________________________

Address:___________________________

____

Working Title:_____________________

Unit No. & Title:__________________

____

Date Submitted:____________________

Hours Spent on this lesson:________

(Block below for instructor use)

Date Received:_______________

Date Returned:_______________

Comments:

____
(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 8

OCEANS AND ESTUARIES

Unit No. 8

Oceans and Estuaries

Reading Assignment:

Odum p. 324 - 362

Wagner, Chapter 9

Hinrichs, Population, Environment, and People, papers by Hedgepeth (p. 47)

Brubaker, p. 114

Turn in completed report from Unit 7.

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name:______________________________

Address:____________________________

____

Working Title:______________________

Unit No. & Title:____________________

____

Date Submitted:____________________

Hours Spent on this lesson:________

(Block below for instructor use)

Date Received:_______________

Date Returned:_______________

Comments:

____

(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet
to your instructor along with the assignment.)

UNIT NO. 9

NATURAL AREAS

Unit No. 9

Natural Areas

Reading:

Attached material

Wagner, Chapter 4

Assignment:

Locate the nearest natural area in your vicinity. (You may already know where this is. If you do not, check with appropriate people in the Forest Service, or Park Service, or the biology department of a nearby university or the state university.)

Prepare a report on this area, which you should visit, including:

1. A description of the area, its vegetation, wildlife, topography, and any other features of interest.
2. A brief history of the area. Is it really undisturbed (by man or his livestock or other human influences)? When was it set up? How is it protected?
3. What kind of plant and animal succession is going on in this area? If fully protected, will it remain as it is now, or will it change? On what facts, is your answer based?
4. What good is it?

Such extraordinary changes have taken place in America since it was first explored and settled by Europeans that few Americans have any very clear idea of what it was like in the "beginning." Some of the most wonderful forests in the world have been almost entirely replaced by farms, cities, towns, and highways. The original windswept prairies have given way to corn and soybean fields squarely bound by fences. The vast grasslands of the West have been subtly but enormously changed by the trampling and chewing of many millions of sheep and cattle and horses. The great American wilderness, with its fascinating array of trees and grasses and flowers, its buffalo and lions, elk and antelope, wolves and bears, and its magnificent variety of birds, is now about gone.

We still have left some good-sized tracts of wild country in our high western mountains, remote and hard to reach, and hence, fairly well preserved so far. In the central and eastern portions of America , there are still remnants, most of them small, a few of which are preserved, but most of which may ultimately disappear unless they are thoughtfully protected and carefully managed. There are, it must be admitted, extensive areas of our country where there is no wilderness left at all. But we still have just barely enough left to provide us with fair samples, however, small, of most parts of our original America.

These remaining natural areas are a wonderful heritage. They help us piece together a fascinating picture of the magnificent primeval lands our ancestors entered so many centuries ago. They are of immense scientific value. They show us what the land can do under natural conditions, and they serve as guides in our efforts to manage land for many purposes -- for the conservation of soil and water, forests, grassland and wildlife. In themselves these remnants are natural works of art, as inspiring as the greatest symphonies ever written by men.

It would be well indeed if our children and grandchildren could know first-hand what their country was like when our forefathers first came here. In preserving and protecting these natural areas we are practicing conservation possibly in its finest sense.

It might, perhaps, be fairly suggested that one of the measures of civilization of a country is its attitude toward preserving samples of its natural environment in an undisturbed condition, just as its attitude toward preservation of its artistic and literary treasures is such a measure. At least there seems to be a strong correlation between these things and the impression of civilization. (Report of the AAAS Council Study Committee on Natural Areas as Research Facilities. Nov. 1963 p. 6)

The impressive biological evidence, long misunderstood or disregarded, is to the effect that we humans are a product of our environment. As René Dubos has pointed out -- "The evolutionary steps through which man reached the level of Homo sapiens, explain, for example, why the structure of his backbone can be traced to the early fishes, or why the salinity of his blood still reflects the composition of sea water from which terrestrial life originally emerged."

We disregard such evidence at our peril. We are what our environment has made us. To understand ourselves, we must understand the environment -- the natural conditions -- that have shaped us. These are the natural conditions, for the most part not developed, and still less understood, by men.

It is clear that the American environment in general has changed substantially from what it was five centuries ago. It is also quite likely that this environment had already been changed by human beings that inhabited this country for 10 to 30 thousand years before our ancestors got here. Thus, we might ask ourselves, what is a natural environment? Have we, indeed, ever actually seen one?

We cannot really say that the environment is unchanging. Very obviously it is constantly changing. All the organisms in it -- plants and animals -- change it. So does climate. And so does man. The difference is that man has brought about changes faster and more drastically than any other form of life on our planet. We may think of human changes as "artificial," but man is just as "natural" as any other living organism. He is just as much a part of the environment as any other. We can only say that he seems to have a greater effect on the plants and animals and soil and atmosphere than the other organisms have.

An idea that may help us to understand the situation is the idea of balance or equilibrium among the organisms and the area they live upon. Where all the incredibly complex inter-relationships have come into a balance that persists, then perhaps we can say: here is a natural environment. This is a biological community that will tend to stay in balance -- same general proportion of all the various organisms in it in relation to the soil and atmosphere they inhabit. Automatically, such an environment would be relatively stable. It could accommodate physical and biological changes, but would tend always to return to a balanced condition.

All of this may seem to be theoretical or philosophical -- and so it is. What we need to consider though, is a stable, balanced environment, rather than a primitive or "original" or primeval environment. The changing, stabilizing, balanced environment our ancestors invaded is one in which we are greatly interested. What was this environment like? Do we still have some parts or portions of it that we can study and from which we can learn? Where are they and what are they like? Can they tell us anything we can use -- in our attempts to adjust our own actions so as to fit into and become a part of an environment that will be of greatest value to us?

These questions are difficult, but we do have answers for most of them, answers that make scientific sense. Our answers may not be as sound, ecologically, as they should be, but they are good answers, as far as we know at the present time.

For many years now, we have been trying to save and hold "inviolate," various biological communities. The areas we select are samples of balanced environments, or better, natural areas that have been the least changed or affected by man. From a purely theoretical point of view a redwood forest that has been cut down would be one of these balanced areas, since the redwood will recover, and within several thousand years, our natural area will be in good shape again. Obviously, this is unsatisfactory if not ridiculous. Who wants to wait that long to see the balance restored? What we do, of course, is to pick areas that are the least changed, that are, in other words, very close to being a stable community and as close as possible to a balanced situation.

Ecologists have identified some 160 types of biological communities in the United States. We ought to be able to set aside at least a few samples of each type. Such areas are what we come now to discuss.

From what we have talked about so far, it is easy to see that we can scarcely expect to preserve areas of really "original" America. They have already been changed -- some only a little, some radically. But we can preserve areas that are as close as possible to the "original" condition. A bird or two, a plant, may have gone, but otherwise things appear much like they once were.

Now, of course, changes go on under natural conditions all the time. Nothing in nature remains static. Trees grow up and die or burn down from lightning or blow down in a hurricane. Various animals succumb to disease and disappear, or their habitats are destroyed by drought, fire, or other natural disasters. These changes are not necessarily related to man at all. All the "protection" we can offer will not prevent natural changes -- minor or major -- from taking place, just as they have and always will.

What we do really, when we "protect" a natural area, is to try to prevent any man-made changes -- but we let the natural ones go on. At least, that is the way we intend to do it. But we protect it from fire, which is a natural agent of change. We can't afford to have the big predators -- bears, lions -- in the area, unless it is very large indeed. So we keep their numbers down. And we do such things to keep the area as unchanged as we can. This is influence, human influence.

But when we try to protect an area of fine, original pine trees, we're not about to let a lightning-caused fire destroy the area, natural or not.

Conserving Natural Areas

When we talk about the preservation or conservation of our remaining "original" natural areas, there is one thing we must keep in mind. Every bit of the natural area has been changed. We have no wild areas anywhere that are precisely the same as they were even when the earliest explorers from Europe first came here. Sometimes the changes have been ever so slight. Sometimes they have been very great. But everywhere there has been change brought about for the most part by us Americans.

There is no natural area left anywhere along the eastern side of our country that is the same as it was when the Vikings landed nearly a thousand years ago. A number of animals that once lived there are now exterminated, and so are some trees and other plants. Passenger pigeons are gone, as everyone knows, and so are the Carolina parakeets, the great auks, the heath hens, the wood buffaloes, the eastern elk, the Florida wolves, the eastern cougar or mountain lion. These animals, and a number of others, are extinct. There is a considerable number more that appear to be headed in the same direction.

Several plants are gone completely, the names of which would be only a latin phrase to most people. The beautiful Franklinia, found long ago in one small spot in Georgia, has never been found wild since. We have it only in gardens. The eastern chestnut, majestic tree of our eastern mountains is now nearly eliminated from our remaining forests -- and for the most part these have been cut over many times. In 1962 scientists announced that the Florida nutmeg -- a unique and famous tree known to occur at the boundary of Georgia and Florida -- has been all but wiped out. A few specimens survive in gardens, but the wild trees are all dead, except an occasional one with a few sickly sprouts at the base of the skeleton trunks. A fungus disease is suspected.

All these plants and animals were here when Columbus reached the Indies, and most of them were still here when George Washington was our first President. Some have been exterminated during the lifetime of many people now living. More will probably disappear during your lifetime.

Now the point about this is that when a bird or a mammal or a plant -- or any other living thing -- becomes extinct, the place where it lived is changed by its disappearance. The change may be small, it may be very obvious, it may appear major in character, but when a living organism disappears from the earth, the change can never be reversed.

Managing Natural Areas

Managing a natural area, to keep it natural, takes a great deal of knowledge and skill. Many people believe that all you have to do is leave the area alone. But this is almost never possible. Livestock cannot be permitted in such an area, so it usually has to be fenced. If a fire were to start in it, we would need to extinguish the flames as soon as possible, otherwise the area might be destroyed -- as a balanced environment. We must watch it carefully not only to prevent fires, but also to prevent careless people from damaging it. People dump tin cans, bottles and other rubbish "out in the woods," and some may try to cut Christmas trees or break off branches of dogwood, pick the spring flowers, shoot the squirrels, build a campfire -- and so on and on. Obviously the area has to be guarded against this sort of thing.

But there are other problems. If the area harbors, say, prairie dogs, then if too much grass is permitted to grow, the prairie dogs will not be able to remain. Or, if the area has a grassy meadow fed on by wild geese, if the grassed area is let grow up into brush, the geese will leave, for lack of preferred food.

These examples -- most of them much simpler than many of the problems -- illustrate the fact that to keep an area the way you want it requires management. Under natural conditions, the plant life and the animal life of an area are always in a constant state of change. You may not notice this from one year to the next, but in ten, twenty, or more years, the changes may be considerable.

If an area is set aside as a natural preserve for a specific mammal or bird, then the animals' habitat has to remain suitable to it. If the habitat changes, the animal will not remain. Similarly, if the area is set aside for a flower or an unusual tree, then the conditions under which the plant thrives will have to remain unchanged. Otherwise the plant will disappear, sooner or later.

On the other hand, natural areas may not require too much management. What we do to keep the area the way we want it must be a balance between things that must be done and things we cannot afford to do. We can -- and we have done so -- make things so attractive for deer that they increase so rapidly they literally eat themselves out of house and home. Over-doing management efforts can be as bad as no management at all.

It is not an easy matter to say with certainty how much land we have in the United States that is preserved and protected in a natural, relatively undisturbed condition. There are many reasons for this.

For one thing, there is no formal system including all natural scientific areas in existence in this country. In Great Britain, there is such a system, administered by the Nature Conservancy -- a government agency quite different from our own Nature Conservancy which is a private organization. Thus, an inventory of such areas means the cooperation of a great many agencies -- federal,state and local governments -- private organizations, and universities and colleges. In these hundreds of organizations, very few have an office or a person "in charge" of natural areas per se.

A great many natural areas are located in preserves set up for some other primary purpose. For example, there are many natural areas well protected in national parks and monuments. Some are to be found in wilderness areas, especially in national forests. There are others, but how many acres they may involve is often not clear. Nor is there necessarily complete agreement among agencies as to what constitutes a natural area and what kind of protection or management it should receive, especially as different from that accorded the area for other purposes.

In 1963 a special committee of the American Association for the Advancement of Science made a report on this. They were studying areas that had been essentially undisturbed, and that could be used for scientific research. This group estimated that some 40 million acres in our country are thus preserved. The total number of such areas was estimated to be about 300.

Fourteen states had less than 10,000 acres each and of these, two had less than 100 acres. Four had between 10 and 20 thousand. Nine had 20 to 100 thousand. Seven had between 100 and 500 thousand. Four had between a half million and a million. Ten had more than a million acres, and three of this ten had 5 to 7 million.

This gives us a sort of rough idea of size, but it tells us nothing about quality. A great many kinds of plant and animal communities are simply not represented, even in the 40 million acres. We are lacking good samples of various kinds of desert lands, of grasslands of the central United States, and we could do with a lot more examples of various types of natural areas in the eastern part of our country.

Besides this, in 1963, the Nature Conservancy published a listing of natural areas set up and administered by colleges and universities. In total some 90 areas involving nearly 53,000 acres, were listed. They varied in size from a few acres to better than 1,000 with one special one 23,000 acres in area. These are areas used for scientific research by the universities.

Then, in 1968, a report was issued on the "Research Natural Areas" that have been established on the federal lands of the United States. As pointed out in the report, the federal government holds title to slightly more than a third of the country, with the largest part in Alaska and the

West. The report was developed by the Federal Committee on Research Natural Areas, a standing committee including representatives of all the federal agencies administering most of the federal lands. A total of 336 such areas were designated. These totals duplicate figures listed above.

The work that has been done on natural areas is relatively informal in nature. A great many scientists, keenly aware of the need to preserve what we can while we can, have joined forces in committees and task forces. But, so far, we lack an agency or authority clearly responsible in America for the preservation and management of all natural biological areas of scientific value. We are dependent on the good will and cooperative spirit of hundreds.

The American Environment

Name: ______________________________

Address: ___________________________

____

Working Title: ______________________

Unit No. & Title: ___________________

____

Date Submitted: _____________________

Hours Spent on this lesson: ________

(Block below for instructor use)

Date Received: _______________

Date Returned: _______________

Comments:

____

(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 10

WILDLIFE

Unit No. 10

Wildlife

Reading:

Wiped Out and Unsung by Solem

A Bright Outlook for Wildlife by Borell

Excerpts from Tennessee Valley Wildlife by Emerson

Wagner, Chapter 16

Assignment:

Turn in the report prepared for Unit No. 9.

A Bright Outlook For Wildlife

By A. E. BORELL

WE have more kinds and greater numbers of game birds, game mammals, furbearers, and game fish in the United States today than were present when white men first set foot on American soil. And our soil- and water-conservation programs should continue to maintain, and even to expand, our fish and wildlife populations and the hunting, fishing, and other recreation that goes with them.

Some people question such optimism. We frequently hear that Man and his activities have seriously depleted our game and fish. We also hear that "Hunting and fishing ain't what they used to be; I have hung up my rod and gun." Even some wildlife administrators tell us that drainage, cultivation, livestock grazing, water control, weed sprays, timber cutting, and modern farming methods are wiping out our game and fish. They would lead us to believe that wildlife is going downhill rapidly and soon will be a thing of the past.

This picture of gloom is not new. Back in 1883, Frances Francis, an English writer, said, "They always tell you things used to be better than they are now, and that something or other is ruining them." Francis was speaking about fishermen. How much basis is there for this kind of anguish and propaganda?

Certainly there have been changes in species and shifts in populations. The passenger pigeon, heath hen, and bison are gone—in their stead we have pheasants, chuckars, Hungarian partridge, and a tremendous population of deer. While many streams and natural lakes have deteriorated and some species of fish have declined, let us not forget that we now have thousands of acres of manmade ponds, lakes, and reservoirs that provide fishing. Many of these are in areas where little or no fishing existed 100, 50, or even 10 years ago.

Recently, I attended a meeting presided over by one of our top game administrators. At that meeting there were indications that Utah, Colorado, Montana, and Wyoming are competing in their efforts to attract out-of-state hunters to help harvest their overpopulations of deer, and in some cases, elk and antelope. We hear reports of overpopulations of deer in Pennsylvania, Wisconsin, Michigan, Texas, West Virginia, California, Arizona, and a few other States. By overpopulation, I mean not merely more deer than the range will carry, but actually more deer than the hunters want to harvest.

Last year, Colorado had the most liberal deer hunting season in the history of the State. This year the license fee will be lower and the bag limit will be even larger. For $12.50, the Colorado resident this year will be able to take 4 deer in large sections of the State. Few hunters or families want more than 1 or 2 deer, but they can have 4 if they want them.

In 1955, I attended a technical session of the Western Association of Game and Fish com-

Pintail ducks at Roach's Run, Va.

Note:—The author is biologist, Soil Conservation Service, Denver, Colo. This article is based on a talk given at the annual convention of the Izaak Walton League, Golden, Colo., June 1957.

All photographs used with this article were furnished by the Fish and Wildlife Service.

missioners dealing with upland game birds. In that session, several game technicians discussed the subject of "How to Get Adequate Harvest of Pheasants, Sharptail, and Blue Grouse"—in other words, "how can we get the hunters to check overpopulation?"

Last year (1956), the legal hunting season on sharptail grouse in North Dakota was more liberal than in many years. Colorado and New Mexico had larger quail populations and longer hunting seasons than for many years.

In the publication, *New Mexico Wildlife* for June 1957, Levon Lee, chief of game management for the New Mexico department wrote, "New Mexico's . . . antelope, elk, mountain sheep, javelina, turkey, and . . . deer continue to increase."

In the June 1957, issue of *Field and Stream*, Conservation Editor, Harold Titus reported that "West Virginia game officials are complaining that their Sleepy Creek State Forest, although it is only 80 miles from Washington, D. C., doesn't attract enough hunters to keep the deerherd within bounds or to make a dent in the population of turkey, grouse, and squirrels. The State is even offering to show hunters the way around the area. . ."

In the June 8, 1957, *Newsletter* of the Colorado Game and Fish Dept., Dean Coleman, fur manager, is quoted as saying, "Colorado's population of furbearing animals is holding up well with some species, such as raccoons and foxes, increasing a bit too rapidly."

Note that these statement report conditions in 1957, not 1857.

Another indication of the abundance of hunting is the fact that in many States we pay bounties or hire hunters to kill pumas, wolves, coyotes, foxes, and badgers. If we were really short of hunting, we would have these animals on our game list instead of on the vermin list. All of them offer excellent sport for the hunter and his dogs.

The spread of native game species to new ranges, especially raccoon, foxes, tree squirrels, and deer on the Plains is notable. Today there are sizable populations of these animals on the Plains in areas where 50 years ago there were few or none. In many cases, this spread is due almost solely to the planting of windbreaks and shelterbelts in areas where no trees previously existed.

Even waterfowl—that wildlife resource which, according to some "prophets of doom," is being destroyed by drainage—has been on the upgrade for several years.

These conditions don't indicate that lumbering, farming, and grazing are wiping out our big game, upland game birds, furbearers, or waterfowl.

In regard to warm-water fish, almost every publication we pick up tells us that our warm-

Wild tom turkeys strutting on a wildlife refuge in Oklahoma.

Deer in the Black Hills region of South Dakota.

water fish populations are being underharvested. This is often true even of trout in water more than a mile from a road. Nevertheless, new reservoir construction, as well as developments in the control of rough fishes and the rehabilitation of lakes and reservoirs, will further increase our warm-water fish and trout producing opportunities.

Furthermore, largely through assistance from the Department of Agriculture, hundreds of thousands of farm and ranch ponds have been constructed during the past 20 years. Many of these ponds are now providing fish for warm-water species and for trout. These small ponds can be fertilized and managed for high production. More research on stocking and managing of farm fishponds, and more technical assistance to farmers on fishpond construction and management problems can increase this fishing resource by perhaps tenfold—maybe more.

Why are most species of fish and wildlife holding their own or increasing in the face of drainage, grazing, lumbering, water control, and intensive farming activities? Among the many reasons are:

1. The cutting of dense stands of timber permitted the growth of grasses, forbs, and shrubs. This increased the carrying capacity for deer, elk, grouse, furbearers, and many others.
2. Heavy grazing of some rangelands by domestic stock favored forbs and shrubs over the grasses. As a result, the carrying capacity for deer, elk, antelope, quail, and rabbits, has gone up.
3. The construction by farmers and ranchers of thousands of reservoirs, lakes, ponds, ditches, and windmills has put water on millions of acres where previously water was the limiting factor for wildlife. Bureau of Sport Fisheries and Wildlife surveys show that in Montana there are about 111,000 ponds, and in South Dakota, roughly 107,000 manmade ponds. In Colorado, over 14,000 ponds have been constructed in the past 20 years. In the United States, over 800,000 ponds have been constructed in soil conservation districts since 1937. These manmade ponds provide water for big game, furbearers, upland game birds, and, in addition to providing drinking water and resting places for migrating waterfowl, many of them produce one or more broods of ducks each year.
4. Soil conservation districts and the Department of Agriculture have sponsored conservation practices such as stripcropping, contour cultivation, proper irrigation, crop rotations, stubble mulching, grassed waterways, improved pastures, range management, farm and ranch ponds, windbreaks, and other erosion-control measures. These practices have slowed erosion, increased

Canada geese on a pond near Horicon, Wis.

Lesser snow geese and Canada geese on Bear River Migratory Bird Refuge, Utah.

the quality and quantity of plant growth, and thus the ability of millions of acres to support more people and more wildlife.

5. Wheat, corn, milo, rice, pasture grasses and legumes, and other farm crops produce high quality wildlife foods in quantities far beyond that produced by the original grasslands, forests, and deserts. Thousands of mallards now winter in Colorado. I am certain that few ducks wintered there before farmers planted winter food in the form of grain crops. It is obvious that pheasants could not have lived in most of the United States prior to the planting of agricultural crops.
6. It is true that large areas of land were cleared and thus many acres of wildlife cover were destroyed. In their place, though, we have thousands of miles of fence rows, windbreaks, shelterbelts, ditchbanks, drainage canal banks, roadsides, grassed waterways, and terraces that provide cover and travel lanes for upland game. Although in many areas there is a smaller total acreage of cover today than 50 years ago, there is more food for many species and far better distribution of cover, in relation to food and water, and, thus a higher carrying capacity for most kinds of wildlife.

There are now over 2,750 soil conservation districts in the United States. In these districts more than 3,000,000 acres of trees have been planted; more than 26,000,000 acres of pasture and range have been seeded; more than 3,000,000 acres have had wildlife practices applied and more than 800,000 ponds have been built. In addition to these conservation practices that have secondary wildlife values, during the past year the Department of Agriculture designated three specific wildlife practices as eligible for cost sharing when applied on Conservation Reserve lands.

The people of the United States and of the world are learning more about the wise use of land and water. I am confident that 10, 50, and 100 years from now, the ability of the land and water, of the United States and of the world, to support people and wildlife will be greater than it is today, and that our populations of fish and wildlife also will be greater.

MORE TIMBER IN NORTH CAROLINA.—The sawtimber supply in North Carolina is better now than it was 17 years ago, and current growth—even in large pine sawtimber—is more than sufficient to replace timber cut, according to a recent survey of the Forest Service. The State had 17 percent more timber volume in 1955 than in 1938, though the average size of trees was smaller and there was a larger percentage of hardwoods.

North Carolina now has 1,200,000 acres more forest land than it had 17 years ago.

WIPED OUT & UNSUNG

ALAN SOLEM

Drawings Courtesy of the Field Museum

Perhaps the saddest aspect of being the curator of a biological collection today is the glum knowledge that each year more of your special world vanishes forever. Its passing causes not a ripple.

Sure, some things are saved. Heroic publicity measures and dedicated fund raising saved for the "Prairie State," Illinois, one scrap of virgin prairie, Goose Lake in Grundy County. One stand of white oaks, Beall Woods, stands near the Wabash River rather than lying as charred barrels in Scotland aging whisky.

I like Scotch whisky, but I also like forests. Our world needs both. The passenger pigeon is gone and books are written about it. The whooping crane barely survives. *Life* magazine (January 9, 1970, p. 84) includes under "trivial trends that point the way" the fact that whooping cranes increased from 33 in 1960 to 55 in 1970.

Yet, when I say that man has wiped out 10,000 species of insects and snails in the last 200 years, at most there are raised eyebrows. "So what?" is the usual comment. Even those most devoted to the preservation of natural areas and the saving of rare and endangered species are unaware of this fact. Under my Christmas tree this winter was a copy of the beautifully produced *Wildlife in Danger*—by James Fischer, Noel Simon, and Jack Vincent. This book surveys the current status of endangered species as determined by the International Union for Conservation of Nature and Natural Resources. It has 149 pages on mammals, 152 on birds, 14 on reptiles, 3 on amphibians, and 13 on fishes. There is no mention of lower organisms.

It is unrealistic to expect otherwise. Western man long has operated with the view that the world is here for human exploitation. This is epitomized by Pope's "The Proper Study of Mankind is Man." We are more than uncaring. We are almost totally anthropocentric [man-centered]. More like man, more interest; less like man, less interest. This shows in our language, our actions, and even the staffing of Field Museum (see table). Yet cracks appear in our egocentric armor. *The Naked Ape* and *The Territorial Imperative* became best sellers by calling attention to the animal aspects of human behavior. Pollution is past the point of being ignored. It is a basic fact that no organism can live on its own excrement. Look at our rivers. Breathe our city air. We have been trying very hard. The tidal waves of debris from our sewers, smokestacks, automobile exhausts, garbage cans, and factory waste outlets threaten disasters. Lip service to a clean environment replaces flag and motherhood in political speeches.

We are learning a lesson known to primitive tribes for many centuries. Man *shares* this world with other organisms. We need them, and they need us. The oxygen we breathe is a waste product of plants. The carbon dioxide plants use is a waste product from animal bodies. Energy from the sun is used by algae and land plants to make organic chemicals. Animals get their organic chemicals either by eating plants or by eating animals that have eaten plants. Decay organisms, mainly bacteria and fungi, reduce the dead bodies of animals and plants to simple chemicals. These are then used again in the cycle of life. All life on earth is linked in a vast interdependent *ecosystem*.

If we break this chain of inert to living to inert, life on earth will cease. Warnings by ecologists of dangers from pesticides, thermal pollution, and habitat destruction appear in mass circulation magazines. By 1972 the words "ecology" and "ecosystem" may be as familiar as "astronaut" and "spaceship." We must have plants, and animals, and birds, and even snails and insects. Yet exploding human populations con-

The anthropocentric staffing of Field Museum

Group of species	No. of species	No. of curators
Man	1	—
Mammals	4,190	2
Birds	8,590	3
Reptiles & Amphibians	8,500	2
Fishes	40,000	1
Lower Invertebrates	175,000	1
Land Arthropods	910,000	2

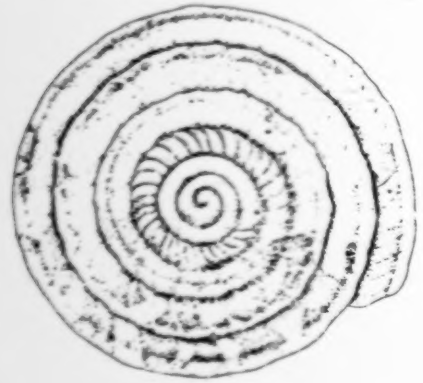
If Field Museum decided to have as intensive a study of land arthropods as we do of mammals, we would need 436 curators for land arthropods. Actually, only about 50 percent of the insect, mite, and spider species are known, while nearly all mammals have been described. A more realistic need would be for 872 curators for land arthropods.

tinue to encroach on the environment—a fancy way of saying wipe it out.

It occurs in big ways. And in small ways. The next 30 years will see all forests in Central America cut down and gone forever. Incredible and pessimistic? Not to a biologist who has been there. Urban areas grow. Suburbs build up to uninterrupted vistas of manicured grass, concrete, and asphalt, at most sprinkled with trash. Many biologists of my generation were weaned on vacant lots, redolent with dusty weeds on hot August days, singing with myriad insects and birds. Between digging forts and playing hide and seek in the long grass our eyes were caught by the red and black of a milkweed beetle, the grace of a fluttering butterfly, or even the shimmering back of a resting slug beneath an abandoned cardboard box. Curiosity, interest, avocation, profession followed in tidal sequence. Now these lots have houses, or at best are neatly asphalted play lots, routinely sprayed against mosquitoes.

Bit by bit the environment changes, variety lessens, and species disappear. It may be robins from a city, buffalo from the Great Plains, or snails and insects from "some enchanted islands" rising dot-like from the vast Pacific. For here alone our 10,000 species vanished, mostly within the span of living centenarians. Item: In the 1870's an American missionary, Andrew Garrett, collected 13 species of endodontid land snails on Rarotonga in the Cook Islands; in 1965 there were only two remaining. Item: Living endodontid land snails were found on Mangareva, Gambier Islands in the 1840's; in 1934 only the dead remains of 25 species were found. Item: Of perhaps 125 species of Hawaiian endodontid land snails still living before 1850, probably less than a dozen exist today. Item: In 1948 a Hawaiian entomologist, Elwood Zimmerman, could state concerning the native insects "that to say a third or more of the species are now extinct would be no exaggeration." Inasmuch as there are perhaps 6,000 species of Hawaiian insects known from collections in this century, this means a mere 3,000 species were gone by 1948. More have vanished since. Add another 2,000 for the Marquesas, denuded of forest to 3,000 feet by the mid-1920's, plus the loss of 2,000 species from the Society Islands—Tahiti, Moorea, Bora Bora. There are still the Austral Islands, Cook Islands, Samoa, Fiji—their vanished species unreckoned. The leeward dry regions of the Hawaiian Islands contained 60 percent of the native tree species. These have been stripped to nearly 5,000 feet. How many species gone? We don't know. But plants, and snails, and insects combined? Ten thousand is a modest estimate.

Why did they go? It was not only by deliberate hunting. It was not all the fault of Western man. When the Maoris reached New Zealand about 950 A.D., there was a bird fauna of perhaps 150 species. The large and edible moas were hunted and killed, but this covers only about 20 species. Another 30 species disappeared by 1900 because of habitat disturbance.



Habitat disturbance brings visions of bulldozers and factories. On islands it is much simpler. Cattle trample through native forest. An ornamental garden fern goes wild and chokes out thousands of acres a year in Hawaii. A potted garden plant from overseas had a few unnoticed ants; within a decade *Pheidole megacephala*, a voracious species of ant, occupied lowland Oahu, destroying insects and snails alike. For several years I've been studying endodontid land snails. On Pacific Islands there is a neat and simple equation: Introduced ants = no ground-dwelling endodontids. Even more so for many insects.

So I'm writing about the species that were, or occasionally (still) the species that barely are. On Upolu, Western Samoa, a beautiful little land snail called *Thaumatodon hystricelloides* was common in the woods behind the port of Apia in 1865. In 1965 it was restricted to high mountain peaks, the only areas from which introduced ants were still absent. The question is not *will* it become extinct, but *when*. Islands were treasure troves of evolution, but the carelessness of man's introductions threatens to turn them into wastelands. Eighty-five of 94 bird species thought to have become extinct since 1900 lived on islands.

But extinction strikes closer to home. A new subdivision in California results in bulldozing the only known habitat of a land snail into oblivion. Colorful Florida tree snails become extinct over thousands of acres in the Miami-Homestead area as the tangles of trees and vines are replaced by houses. Resorts and retirement houses fill the Florida Keys, and more snails are nearly lost. They are gone from their original home, but survivors have been transplanted into the Everglades National Park by a few dedicated naturalists. So some were saved.

Even land snails have a few partisans. And I plead guilty to a somewhat malacocentric outlook. But many, many land snail species are on the verge of extinction. There are only a handful of malacologists. Should the few of us collect and preserve samples from populations of the vanishing species? If we do this, there will be a bottled remnant in museum jars for our successors to study. But if we scramble to snatch these samples of vanishing forms, there is not enough time for study of what we get, nor for attempts to save and preserve. If we study some, then many will be lost without a trace. If we try to save a few, then neither collection nor study is possible.

No choice is easy. The island snails that I now study are vanishing rapidly. Saving them is not possible. Introductions of domestic animals, plants, and insects have set in motion habitat changes that doom the snails to extinction. Unlimited money, help, and cooperation would not be sufficient to reverse the trends. So I collect and I study. When I can, I help efforts to save natural areas and preserve endangered species. This still is little compared with the need.

"Can man survive?" is the question now raised. Environmental catastrophes are predicted and occur. Crash programs on ecology will be called for and organized. The call of "relevance" in teaching and social work is being extended to science and research. The need for practical results to aid man's survival reduces the funds for basic research in the middle of inflation. Our awareness of dependence on other life forms ironically is breeding a new round of anthropocentrism. Will there be room on earth for insects and snails? Will there be room for students of them? ■

Alan Solem is Curator of Lower Invertebrates at Field Museum of Natural History in Chicago. This article is reprinted from the April 1970 issue of the museum's monthly Bulletin.

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name: ______________________________

Address: ___________________________

____

Working Title: ______________________

Unit No. & Title: ___________________

____

Date Submitted: _____________________

Hours Spent on this lesson: _________

(Block below for instructor use)

Date Received: _______________

Date Returned: _______________

Comments:

____

(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 11

THE HUMAN POPULATION

Unit No. 11

The Human Population

Reading:

Population by Van Dersal (attached material). See also Kellogg and Orvedal paper in Unit 6.

Wagner, Chapters 22, 23

Odum, p. 53-56, Chapter 21

Hinricks, entire book, noting especially papers by Hauser (p. 17), Casmann (p. 35), Hardin (p. 59), Shinn (p. 76), and Wald (p. 214)

Brubaker, pp. 32-73, 198-217

Assignment:

Turn in a brief discussion of a subject on which you will prepare a paper. Set forth the major points you plan to cover. (Avoid subjects on which you feel you are already seasonably well informed.)

POPULATION

Most of us know that the number of people in the world has been increasing very rapidly. The rate of increase has been so fast that there is much talk about a "population explosion." Some scientists believe that the enormous and increasing numbers of humans are a grave threat to the future of mankind. They claim that we are very close to entering on a new dark age. There are other scientists who do not think the problem is quite so threatening. But almost everyone who has studied the matter agrees that it is very serious.

The population of the world reached about one billion by the year 1850. In 1930, eighty years later, the population reached two billion, that is, it doubled in 80 years. Thirty years later, in 1960, there were three billion people in the world. This population is growing at the rate of about 2 percent each year. What this means is that unless something happens to change things, the number of people in the world is doubling every 35 to 40 years.

In the United States we took our first census in 1790. At that time there were less than 4 million Americans. In 1960 we had increased to 180 million. In 1970 we went past the 200 million mark. Between 1790 and 1950 our population doubled five times. Our average doubling time is about 70 years.

Elsewhere in the world the doubling time is about 88 years for Europe, 35 years for Asia, 28 years for Africa, and 24 years for Latin America. The rate for the Soviet Union is about the same as ours, that is, 70 years.

It is important to note two things about these figures. The first is that they are only approximately correct for Asia, Africa, and many Latin American countries, although quite accurate for the United States, Europe, and the Soviet Union. The second is that we cannot necessarily predict what the population of the world or any part of it will be by the year 2,000. Many experts have predicted the world population at 7.5 billion by that time. But there are far too many uncertainties involved in making such a prediction. Population experts themselves will tell you that their predictions are only likely to come true if things don't change. And, of course, changes in the world are taking place every day.

Even so, it remains true that the population of the world is increasing and that the number of people is very large and getting larger.

If all the people were evenly spread over the lands of the earth, perhaps the problem of excess numbers would be easier to solve. But the facts are not that way. The population is very unevenly distributed. More and more people are living in cities. About 2 percent of the people in the world were living in cities (with 20,000 or more people) in the year 1800. By 1950 about 20 percent, or one person in five, lived in cities. In the United States, at the time of our first census in 1790, 95 percent of us lived on farms or in places of less than 2,500 people. In 1920, 51 percent were living in urban areas -- central cities of 50,000 people or more than the counties in which they were located. It seems clear, according to the experts, that most -- perhaps 70 to 80 percent -- of our new Americans will probably go or be born into urban places.

The sheer number of people in the world now, the fact that the number is rapidly increasing, and the concentration of people in cities -- all these lead to a series of difficult problems for mankind.

To start with, the obvious question is, how many people can the earth support? So far there is no convincing, factual answer to this question. The truth is, we do not know. But to answer it, we need to think about some other questions.

What about food for the world's billions? Can enough of it be produced to feed 3 billion, 7 billion, 10 billion people? At the present time, about two-thirds of the world's people get too little food of the right kind. Two billion people are undernourished, that is, they are not getting enough food to eat. The food they do get is lacking in proteins or other substances necessary for health. People in this condition easily get diseases, are apathetic and listless, cannot work well, and die sooner than they should. Various estimates put the figure of deaths from outright starvation at some 10,000 humans per day. The answer to our question then is that even now only about a third of the people have enough of the right kind of food to eat.

We could produce a great deal more food than we are producing now. We are cultivating about 3.4 billion acres of arable land. There are another 4.4 billion acres that could be used for the production of crops. We are, in other words, using less than half the arable lands of the world. We could more than double our capacity for producing food without any improvements in our methods.

These facts, and more that follow, have not been given much publicity. They come from studies of the World Soil Geography Unit of the U. S. Soil Conservation Service. Scientists of this unit have been studying the problem for the past 20 years. They have worked with soil scientists in every country. The soils of the world have been mapped and their characteristics have been carefully studied.

It is incorrect to say that we are running out of land. Our soil resources, world-wide, are adequate for the production of enormously greater amounts of food than we are producing now.

Even in the United States some 200 million acres of potentially arable land are not now cultivated. Counting these acres, there is a total of 660 million acres still possible to cultivate in North and Central America. In Africa there are a billion and a half acres yet to be so used. In South America there are about 1.4 billion such acres. In Asia there are about 207 million acres that could be cultivated, and in the Soviet Union there are 270 million acres more. Even Europe has a potential of 50 million acres more than are presently being used for the production of cultivated crops.

Increasing the area we use to produce cultivated crops is clearly one way we can produce more than twice as much food as we are producing now. The trouble is that the people of the world are not distributed in the same way as the soils. But there are two other ways to increase food production.

We can increase the yields from the cultivated soils. Actually, we already know how to double production in some areas. We can increase production to 5 or 10 times what it is in many regions. And in some places, we could do even better than that. As we make these statements, let us note that we are talking about modern management and technology that can be applied, right now. That is, we are already able to do this, with very little special research. Besides this, where we cannot transfer our technology, lock, stock, and barrel, we can transfer our research methods. Vast areas of the tropics fall in this category. As Dr. Charles Kellogg, foremost soil scientist of the United States, has remarked, "The soils of the tropics are not at fault; we have only to learn how to use them."

The third way we can use to increase the food supply is to put in use improved methods of processing and storing the foods we produce. This means cutting down losses from insects, fungi, bacteria, and rodents. It also means handling perishable foods by freezing or canning. In other words, if we can harvest, store, and distribute food with little or no waste, we can materially increase the amount of food that reaches the people who need it.

Getting food to every person in the world is obviously a very complicated matter. There are many important factors involved -- land, technology, processing, and numerous others. The point though, is, we have the land and the know-how. What we need are systems that will get the job done.

A prime conclusion of ecology is that species whose populations exceed or approach too closely the carrying capacity of resources in the space occupied undergo reduction. Such reductions are often severe and may lead to extinction because of disease, pestilence, predation, or agressive competitors. Although it is true that man has repeatedly succeeded in increasing both the space he occupies and its carrying capacity, and that he will continue to do so, it is also clear that both the occupiable space and its carrying capacity have finite limits which he can approach only at great peril.

Only two things seem certain: there are going to be more people in the future and they will live in denser aggregates. The number of people to be accommodated by the end of the century, moreover, adds a new dimension to current crises. To accommodate these populations, the developed world will require, by the year 2000, additional urban facilities equivalent to all of those already in existence, and correspondingly more for the underdeveloped world. This calls for an entirely different view of our cities and their resource requirements than if we think only of ameliorating specific crises step by step as they arise. Complete urban renovation, the creation of new and better living clusters throughout the country, and better and more diversified use of suburban and rural space are a big order; but it is an order that is practicable, necessary, and urgent. There is no simple "best solution." A variety of solutions must be tried, and for all of them the resource component (including clean air and water) will be central.

Nutrition is the first essential; yet problems of distribution, of local failure to exploit potentialities, and with social customs that dictate what food is acceptable are more immediately urgent than the problem of quantity of food available or producible on a global scale. If present world food production could be evenly rationed, there would be enough to satisfy both energy (calories) and protein requirements for everyone--although with drastic reductions for the new affluent. All-out effort, including the provision of ample fertilizer, and genetic, ecological, and chemical research, could probably quadruple production from the lands and double production from the waters by the end of the century. If such increased production were evenly distributed, it could keep up with population growth expected during the same time and even permit some improvement of diet. But will such all-out effort be started and sustained?

---In Resources and Man, P. 2. 1966
National Acad. Sci. and Nat'l Res. Council

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name:____________________________

Address:____________________________

____

Working Title:____________________

Unit No. & Title:__________________

____

Date Submitted:____________________

Hours Spent on this lesson:________

(Block below for instructor use)

Date Received:______________

Date Returned:______________

Comments:

____

(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

Unit No. 12

Solid Waste

Reading:

Excerpts from Soil Waste Survey, attached.

Wagner, Chapter 21

Odum, pertinents parts of Chapter 16.

Assignment:

Report on how solid waste is disposed of in your area. Do not include human sewage. Include garbage, paper, metals, glass, trash, street sweepings, etc.

The National Solid Wastes Survey

An Interim Report

U. S. Department of Health, Education, and Welfare
Washington, D. C.
October 24, 1968

Sample Representativeness and Community Data

by Anton J. Muhich*
1968

Although 38 states are in receipt of planning grants, only 30 states and the District of Columbia had contributed data to our survey before July 1. 1968. However, an additional 3 states, Iowa, Indiana, and Kansas, were partially surveyed by personnel of our Program in cooperation with the state agencies and that data is included in our analysis (Figure 1).

The data we will be presenting this morning is from 6,259 communities, representing an estimated 92.5 million persons or approximately 46 percent of the population of the United States. Statistically speaking, our sample is quite large.

Our sample, on a population basis, is approximately 75 percent urban, the remainder being rural. This is to be compared with an estimated 73-percent-urban population of the nation in 1966.

For administrative purposes, the Department of Health, Education, and Welfare divides the United States into nine regions
The Bureau of the Census has also divided the country into nine areas using a socioeconomic criteria. These census divisions, although not matching exactly, are not dissimilar to the HEW regions. We felt, therefore, that if our current sample represented each HEW region, it would represent the nation.

---

*Chief, Systems and Operations Planning, Solid Wastes Program

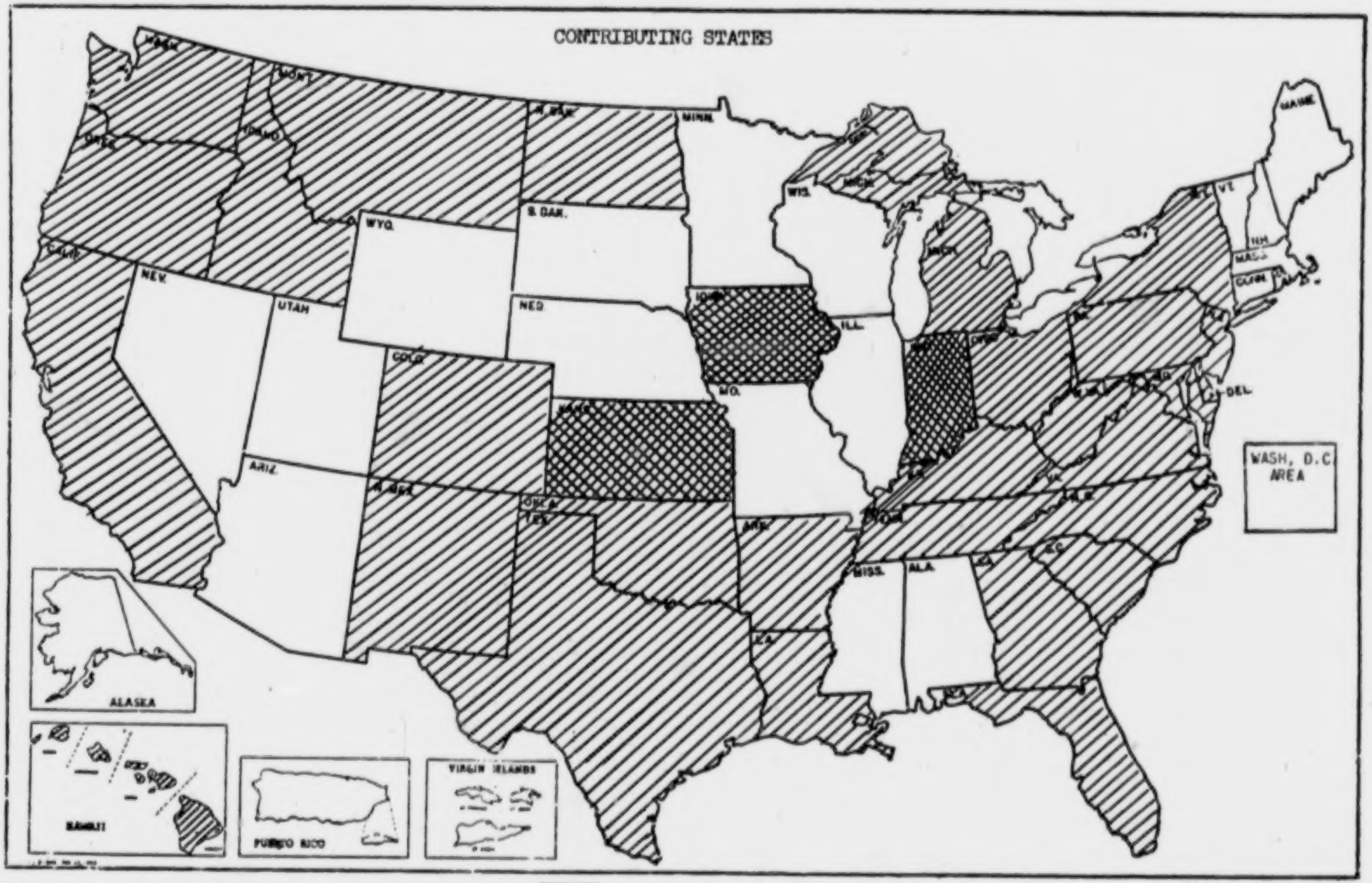

CONTRIBUTING STATES
WASH.
MONT.
N. DAK.
MINN.
IDAHO
OREG.
WIS.
MICH.
MAINE
VT.
N.Y.
N.H.
MASS.
CONN.
S. DAK.
WYO.
CALIF.
NEV.
UTAH
NEB.
IOWA
ILL.
IND.
OHIO
PA.
COLO.
KANS.
MO.
DEL.
WASH, D.C.
AREA
ARIZ.
N. MEX.
OKLA.
TEX.
ARK.
TENN.
N.C.
S.C.
MISS.
ALA.
GA.
LA.
FLA.
ALASKA
HAWAII
PUERTO RICO
VIRGIN ISLANDS

Figure 1. Contributing states. Thirty states ▨ contributed data to the 1968 National Survey of Community Solid Waste Practices. Three states ▩ were partially surveyed by the Solid Wastes Program, and that data is included in the analysis.

The Role of Facilities and Land Disposal Sites

by Albert J. Klee*

(1968)

The general purpose of the land disposal investigation aspect of the Survey is to determine the disposal capabilities, the costs and method of operation of all land disposal sites within a state. The current status of the sample stands at a little over 6,000 sites where for purposes of the Survey, a land disposal site includes any location, whether publicly or privately owned or operated, on which there is dumping of solid wastes by public or private collectors. Included are any privately owned locations where householders or other persons dump their refuse with the permission of public authorities and the private owner. Other dumping sites of such magnitude as to require public attention by state or local authorities also are covered. However, so-called "promiscuous," or unauthorized dumps at the roadside or in public or private areas on which dumping occurs on an irregular or infrequent basis, are not considered land disposal sites for these reporting purposes.

Private sites owned and operated by industrial, commercial, or institutional establishments, and used solely for disposal of their own solid wastes, are not the specific object of the Survey. However, if these sites were surveyed, the information was processed along with the others, in order that such data not be lost for posterity.

---

*Chief, Operational Analysis, Systems and Operations Planning, Solid Wastes Program

The survey for land disposal sites encompasses four general areas of information. These areas are as follows: a community description, a description and evaluation of the site, quantitative data such as tons delivered to the site, and fiscal data such as operating costs. The relationship of the characteristics of the community to these other areas requires a somewhat sophisticated analysis, and such results are not available at this time. However, it is possible to compare the involvement of the public with the private sector, with regard to operation and ownership of land disposal sites.

Considering all 6,000 sites, we find public operation of 79 percent of them, the remainder being operated privately. Because many municipally-operated sites are leased, however, the fraction publicly-owned is somewhat lower, about 63 percent. The public involvement is, nonetheless, considerable.

The Survey form provides for an answer, by the investigator, to the following question: "Is this a sanitary landfill?" The answer is based upon the interviewer's interpretation of the term, no guidelines being provided by the Survey instructions. Fourteen percent of the 6,000 sites were judged by the interviewers to be sanitary landfills. However, the Survey form itself permits a fair evaluation of the site under consideration. Accordingly, special calculations were made based upon the following criteria for a site to be termed "sanitary": (1) the site must have daily cover; (2) the site must not practice open burning; and (3) the site must not have water pollution problems. Utilizing these somewhat modest criteria, the 14 percent of the fills termed "sanitary" were evaluated and, in the end, almost two-thirds were rejected as being unacceptable. In reality, then, only 6 percent of this sample of 6,000 can be reasonably characterized as "sanitary landfills." This would suggest that perhaps there is still some confusion about this term, and that some retraining is in order.

What is wrong with our sites? Only 14 percent of the sample indicated that daily cover was used; 41 percent indicated no cover at all. Only a bit over one-quarter of the sites have an acceptable appearance, and there is some form of open burning on three-quarters of all the sites investigated.

Sanitary landfilling, of course, costs more than inadequate landfilling. The sanitary 6 percent of the 6,000 sites investigated (which handled, on the average, about 27,000 tons per year at each site) indicated an average total operating-plus-amortized capital cost of $1.05 per ton; for a sample of inadequate sites of about equal size this was 70¢ per ton. However, the average inadequate site accepted 11,000 tons of wastes per year at a cost of 96¢ per ton. For sanitary landfills of this size, the average cost was $1.27 per ton. To upgrade all current operations, not just those represented by the sample, it is estimated that some $244 million of capital funds would have to be invested over a period of ten years for equipment alone. An additional $81 million per year would be needed in operating funds. These figures do not include the costs which would be involved in supplying the cover needed to eradicate the prior insults to our environment, nor do they reflect the fact that sanitary landfilling consumes land at a rate 71 percent greater than does inadequate landfilling. With regard to the latter, however, it must be remembered that new technology may greatly modify this present land utilization picture.

An investigation of solid waste facilities is also part of the Survey. This is intended to provide information about the operating characteristics and capabilities of all solid waste reduction or disposal facilities within a state, other than land disposal sites. Such facilities include incinerators, grinders, crushers, transfer stations, compost plants, conical burners and hog feeding lots. Not included, however, are on-site disposal or reduction facilities such asapartment house incinerators and household garbage grinders. Private facilities owned and operated by industrial, commercial, or institutional establishments and used solely for reduction or disposal of their own solid waste are not the primary object of the survey, but such are not excluded if they are surveyed.

Public ownership and operation is involved in 96 percent of the 142 incinerators, 76 percent of the 43 transfer stations, and 59 percent of the 23 conical burners included in the sample. Such facilities are generally located in areas zoned for industry, although one-quarter of all incinerators are located in residentially zoned areas. These incinerator facilities, however, are more sightly than the other facilities noted. Only two-thirds of the transfer station and one-third of the conical burner operations had a satisfactory appearance. In general the 262 hog-feeding lots studied had a more sightly appearance, relevant to their location, of course, than had most conical burners!

The average incinerator processed 188 tons per day, but this low figure is partly due to the small input of those incinerators constructed prior to 1950. The average daily input to incinerators built after 1950 is between 230 and 400 tons. Input to the transfer stations studied averages 375 tons per day and to the conical burners, 41 tons per day. The average hog-feeding lot consumed about 4 tons per day of garbage. It is estimated, from the survey data, that approximately 8 percent of the solid wastes collected in the United States is burned in incinerators, and that almost 4 percent of the garbage collected is consumed by hogs.

The operating costs, per ton, of incinerators, transfer stations and conical burners are approximately $4.50, $1.10 and $1.60 respectively. For capital costs, the analogous figures are $7,100, $1,100, and $1,700.

As disposal in conical burners is merely a controlled form of open burning, our primary interest is drawn to bona fide incinerators. It is possible to classify survey incinerators into three types. Class 1 incinerators are defined as those satisfying the following criteria: (1) they were constructed in or after 1950; (2) they have two or more furnaces; (3) reduction is a minimum of 75 percent by either weight or volume; (4) the facility has operating air pollution equipment. Class 2 is identical except for the air pollution criterion. Class 3 encompasses all other incinerators. As it turns out, however, all of the criteria for these classifications can be related to the age of the incinerator. The newer incinerators, for example, are the ones tending to have operating air pollution equipment. Thus, the three classes can be adequately characterized by their average ages.

It is possible to compare the reduction capabilities of incinerators in age classes selected on the basis of the previously-stated criteria. By weight these figures are 79, 70, and 65 percent respectively; by volume the corresponding figures are 85, 82, and 76 percent.

This now permits a comparison of incinerator operating costs not only on a tons-in basis, but on a tons-reduced basis as well. On a tons-in basis, the operating costs of the first two incinerator groups are $3.27 and $4.05 per ton respectively. The last category has an operating cost of $5.37 per ton processed. When placed on the basis of tons-reduced, however, these costs are $4.06, $5.79, and $8.26 per ton, respectively.

This, then, is a sample of the information currently being gleaned from the survey results. With time, of course, more ambitious and sophisticated analyses will be made to determine the complete role of facilities and land disposal sites in the overall solid wastes picture.

The Challenge That The National Survey Presents

by H. Lanier Hickman, Jr.*

(1968)

The data presented by Dr. Muhich and Mr. Klee indicate in definitive terms the magnitude of the problem that this country faces in solid waste management. The data provided serve also as indicators of what action must take place now and what planning is necessary for the future to assure protection of the environment.

It is significant that at present approximately 12 percent of the residential population receives no formalized collection service, and that another 11 percent receives only partial service. As we increase our efforts to improve solid waste management practices this deficiency must be reduced. This will require a more positive attitude on the part of government and industry to assure that these services are provided. Additionally, 14 percent of the population is served by systems that require separation of wastes at the source, yet their disposal operations have been combined. There is a need for review and updating of these collection systems to reflect contemporary technology. This review and updating will require initiative by personnel in the public works field to stimulate the political sector to support such efforts.

---

*Chief, Technical Services, Solid Wastes Program.

It is inconceivable that this nation, which is making great strides in the control of water and air pollution from industrial sources, can ignore an industrial solid waste volume of such magnitude as that being discharged by municipal sources. It is significant that the National Survey can provide little information about industrial solid wastes. This lack of information indicates local government's reluctance to regulate or assist in the management of these wastes--a responsibility that is rightfully theirs. Too long has industry been left to fend for itself in solid waste management. The absence of uniform regulations and control has left industry with no option but to seek the easiest and cheapest method of management to remain competitive; this should not be. Uniform regulations and local government interest would require standard methods of management by all industry and allow the integration of municipal and industrial solid waste streams for better management.

This country has over 12,000 land disposal sites being utilized by collection services, control of which 94 percent are unacceptable and represent disease potential, threat of pollution, and land blight. By no stretch of the imagination do these sites resemble a sanitary landfill. The waste management field must face the challenge of studying and evaluating these sites to determine their ability for conversion to sanitary landfills. We must develop the necessary plans, finances, and action programs to convert those sites that can function as a sanitary landfill. In many instances it will be necessary to close and abandon many of these sites. Local government then must locate and develop new sites now for immediate use and to provide necessary capacities for the increase of the future.

There are approximately 300 incinerators in this country, 70 percent of which are without adequate air pollution control devices. Many produce residues and quench waters that are released into the environment without adequate treatment and control. These incinerators must be studied, evaluated, and upgraded to meet the more stringent pollution control regulations now being promulgated in this country. In many instances, complete abandonment of these facilities will be necessary because of their antiquated designs and capabilities. Because many communities are without adequate space for sanitary landfill, new incinerator plans will be needed. The current level of the solid waste load being treated by incineration (8%) may have to be increased to help do the job.

All of these needed and necessary improvements and increased efforts are going to require large increases in manpower, capital investments, and operating expenses. To operate existing disposal sites as sanitary landfills may require well over 10,000 new sanitary landfill operators. Further, efforts must be made on an intensive capital development basis to provide the maximum amount of automation and control for incinerators and the minimum amount of manpower. The current concept of the manpower required in incineration operation must be completely changed. We can no longer afford to overstaff our incinerators in an effort to operate antiquated and poorly designed facilities beyond their capabilities. To attract and retain the manpower with the qualifications needed, salaries and benefits for solid waste personnel must be increased severalfold. The solid waste management field, both public and private, must make efforts to train personnel and provide the opportunity of a feeling of pride in their work.

Finally, those working in solid waste management must decide what is going to be required to upgrade, improve and enlarge their systems to the levels necessary to protect the environment and provide adequate services at a reasonable price. We must begin today to develop the timeframe necessary for financing the program development that will allow for a reasonable and rational management program at all levels of government. This timeframe must be developed so that government and the general public can begin to understand the benefits and costs of adequate solid waste management. We must begin now.

Mr. Vaughan will now summarize the Solid Wastes Program presentation and draw conclusions for the National Survey.

National Solid Wastes Survey

Report Summary and Interpretation

by Richard D. Vaughan*

What do these preliminary results imply about the solid waste problem in the United States? Up to now, when anyone asked how much solid waste is collected in this country, the usual response was either 3.5 or 4 or 4.5 lbs per person per day, depending upon who was answering the question. Our Survey results show that the average amount of solid waste actually collected in this country is over 5.3 lbs per person per day, or more than 190 million tons per year. What does this mean in terms of future collection of solid waste materials? During the past 5 years the per capita expenditure for consumption of durable and nondurable goods, rose by about 4 to 6 percent. Since production and eventual discard of these goods are responsible for the waste materials, it would be logical to suppose that the per capita waste production will increase at a similar rate. Assuming the conservative 4 percent annual increase in per capita generation, the amount of material to be collected through municipal and private agencies will rise to 8 lbs per person per day by 1980. Assuming a national population of 235 million by 1980, this means that over 340 million tons of solid waste will be collected.

---

*Chief, Solid Wastes Program.

But these figures reflect only the amount of material that is collected. It must be recalled that 10 to 15 percent of household and commercial wastes are collected or transported by the individual generating the waste. Approximately 30 to 40 percent of the industrial wastes are also self-collected and transported. Additionally, local regulations -- or lack of them -- permit over 50 percent of our population to burn some type of household waste in their backyards. About 45 percent of commercial and other establishments are also allowed to practice controlled open burning of some type. Thus, although the amount of waste material that has to be collected is staggering in itself, the amount of waste material that has to be collected is staggering in itself, the amount of material that is actually generated and could pose potential collection problems is even more impressive. Conservative estimates indicate that 7 lbs. of household, commercial, and municipal wastes are presently generated per person per day; this totals over 250 million tons per year. To this must be added our estimate of over 3 lbs. per person per day for industrial wastes, amounting to an additional 110 million tons per year. Thus, estimates for 1967 indicate that over 10 lbs. of household, commercial, and industrial wastes are being generated in this country for every man, woman, and child, totalling over 360 million tons per year.

To these figures we must add over 550 million tons per year of agricultural waste and crop residues, approximately 1.5 billion tons per year of animal wastes, and over 1.1 billion tons of mineral wastes. Altogether, over 3.5 billion tons of solid wastes are generated in this nation every year.

In the Survey it was seen that, on the average, almost $5.40 per person was budgeted by communities for collection activities. An additional $1.40 was budgeted by communities for disposal activities, giving a total per capita expenditure of $6.80 for both collection and disposal. Thus the total amount budgeted by municipalities is approximately $1.6 billion per year. But this figure does not include expenditures related to solid waste management which are of a nonbudgeted nature. This means, for example, that any monies expended for capital improvements and construction that are supported by bond issues and retired out of the general municipal budget are not included. It has been estimated that expenditures of this type would add about $100 to $120 million to the expenditure for municipal solid waste management, giving a grant total of over $1.7 billion per year.

We have seen, however, that the investment in both manpower and equipment by the private sector is greater than that of the municipal sector so far as collection activities are concerned. Since collection expenditures amount to approximately 80 per cent of the budgeted municipal expenditures, we estimate that the yearly expenditure by the private waste management industry is approximately $1.8 billion.

These figures, of course, do not take into consideration the investment by individuals or private industrial organizations, that, because of necessity or preference, handle and dispose of their own waste materials. Considering the per capita investment in refuse containers, garbage grinders, on-site and backyard incinerators, and the money invested by industry for transporting and disposing of their own material, we estimate that the expenditure in the individual sector is about $1.0 billion annually. Thus, our current estimates of the annual expenditure to handle and dispose of the household, commercial, municipal, and industrial solid waste material in this country is $4.5 billion per year.

But, even with this impressive total expenditure, it must be concluded that present collection and disposal systems in this country are not really adequate. I believe the fact that 94 percent of existing land disposal operations and 75 percent of incinerator facilities are inadequate is a national disgrace which must be corrected if our environment is to be properly protected. In order to provide complete collection of household, commercial, and industrial waste materials, and, moreover, to upgrade the frequency of collection of these materials, it is estimated that an additional 12 percent of our total expenditures, or $540 million a year, must be allocated for operating expenses; this would entail an additional $20 million a year in capital expenditures for trucks and other equipment. Similarly, to upgrade our land disposal operations, an additional $80 million per year is needed in operating funds, while a total of $240 million, or almost $50 million a year for the next five years, is required for capital expenditures. Thus, an additional $130 million per year is required to upgrade our current land disposal operations.

But we must also rectify our past mistakes. If the cost of converting and covering existing open dumps is only 65 cents a ton, and if these dumps are converted at a rate equal to current production, over $100 million per year for five years would be required to complete this task.

It is estimated that approximately $150 million is required to construct new incinerators for replacement of existing inadequate incinerators and conical burners. An additional $75 million is required for air pollution control equipment to upgrade or replace existing inadequate incinerators.

In summary then, it is seen that approximately $560 million per year is required to upgrade our current collection systems. Approximately $230 million per year is required to eliminate the open dumps now in use and improve the level of our sanitary landfill operations. An additional $45 million per year for five years will be required to provide adequate incinerator capacity. This represents a total of $835 million per year for five years required to upgrade existing collection and disposal practices in this country to a satisfactory level. This total is in addition to the estimated $4.5 billion spent annually for solid waste management. To these figures must also be added each year 4 to 6 percent of the previous year's total expenditure to allow for costs due to population growth and increased per capita generation of solid waste. This additional expenditure represents an increase of approximately 18.5 percent over the present funding level, which is not doing the job.

I should point out that the cost estimates are based upon the current ratio of land disposal practice to incineration. If this ration changes in the future, the cost figures must be adjusted accordingly. The cost estimates are also based upon use of current technology, current environmental control requirements, and constant dollars.

Thus we have presented a status of current solid waste management in this country and the costs required to upgrade this practice to a level that we as a nation can consider satisfactory and which I believe citizens will increasingly come to expect. The National Survey which is actually a Federal-State cooperative venture represents the best current estimate of solid waste management practice and problems in the United States today. I say estimate because most of the states found that very few records on the type, characteristics, sources, amounts, and disposition of solid wastes are actually kept. We all recognize the necessity to have good data for solid waste planning and problem solving, not only for the long term but on a daily basis as well. Additional effort will be made to stimulate record keeping at the local level so that even more meaningful information can be collected and evaluated.

The Solid Wastes Program, through sponsorship of research, and through various forms of financial assistance for planning and demonstrations, is furthering the technology of solid wastes management. But the application of this technology rests primarily with you--city and county public works officials, and those in the private sector engaged in solid waste management. The time to begin improving solid wastes practices is now. Fortunately, immediate improvement in solid waste management doesn't have to await some new technological breakthrough. If we will only apply, on a nationwide scale, the best existing technology, we will have gone a long way toward ending the environmental blight and hazard which can no longer be accepted.

The theme of this year's annual meeting of the American Public Works Association is "Changes in Man and his Environment." I believe we have pointed out some very significant changes that man must make in his environment if we are to assure that the environment of the future adequately protects the public health, natural resources and scenic beauty of this nation. Let us work positively together for a better tomorrow.

Excerpts from

Solid Waste Management

Prepared by an Ad Hoc Group

for

the Office of Science and Technology

Executive Office of the President

Washington, D. C.

May 1969

TABLE 2. COMPOSITION OF SOLID WASTES FROM URBAN SOURCES

Urban Sources	Waste	Composition
Domestic, household	Garbage	Wastes from preparation, cooking and serving of food; market wastes from handling, storage, and sale of food.
	Rubbish, trash	Paper, cartons, boxes, barrels, wood, excelsior, tree branches, yard trimmings, metals, tin cans, dirt, glass, crockery, minerals.
	Ashes	Residue from fuel and combustion of solid wastes.
	Bulky wastes	Wood furniture, bedding, dunnage, metal furniture, refrigerators, ranges, rubber tires.
Commercial, institutional, hospital, hotel, restaurant, stores, offices, markets	Garbage	Same as domestic.
	Rubbish, trash	Same as domestic.
	Ashes	Same as domestic.
	Demolition wastes, urban renewal, expressways	Lumber, pipes, brick masonry, asphaltic material and other construction materials from razed buildings and structures.
	Construction wastes, remodeling	Scrap lumber, pipe, concrete, other construction materials.
	Special wastes	Hazardous solids and semiliquids, explosives, pathologic wastes, radioactive wastes
Municipal, streets, sidewalks, alleys, vacant lots, incinerators, power plants, sewage treatment plants, lagoons, septic tanks	Street refuse	Sweepings, dirt, leaves, catch basin dirt, contents of litter receptacles, etc.
	Dead animals	Cats, dogs, horses, cows, marine animals, etc.
	Abandoned vehicles	Unwanted cars and trucks left on public property.
	Fly ash, incinerator residue, boiler slag	Boiler house cinders, metal scraps, shavings, minerals, organic materials, charcoal, plastic residues
	Sewage treatment residue	Solids from coarse screening and grit chambers, and sludge from settling tanks

TABLE 6. COMPOSITION AND ANALYSIS OF COMPOSITE MUNICIPAL REFUSE (1966)[a]

	Components	Percent by weight
1	Corrugated paper boxes	23.38
2	Newspaper	9.40
3	Magazine paper	6.80
4	Brown paper	5.57
5	Mail	2.75
6	Paper food cartons	2.06
7	Tissue paper	1.98
8	Wax cartons	0.76
9	Plastic coated paper	0.76
10	Vegetable food wastes	2.29
11	Citric rinds and seeds	1.53
12	Meat scraps, cooked	2.29
13	Fried fats	2.29
14	Wood	2.29
15	Ripe tree leaves	2.29
16	Flower garden plants	1.53
17	Lawn grass, green	1.53
18	Evergreens	1.53
19	Plastics	0.76
20	Rags	0.76
21	Leather goods	0.38
22	Rubber composition	0.38
23	Paint and oils	0.76
24	Vacuum cleaner catch	0.76
25	Dirt	1.53
26	Metals	6.85
27	Glass, ceramics, ash	7.73
28	Adjusted moisture	9.05
	TOTAL	100.00

[a] Source: Kaiser, E. R. Chemical analyses of refuse components, 1966.

TABLE 8. SOURCES AND TYPES OF INDUSTRIAL WASTES[a]

Code	S. I. C. Group Classification	Waste generating processes	Expected specific wastes
17	Plumbing, heating, air conditioning Special Trade Contractors	Manufacturing and installation in homes, buildings, and factories	Scrap metal from piping and duct work; rubber, paper, and insulating materials, misc. construction and demolition debris
19	Ordnance and accessories	Manufacturing and assembling	Metals, plastic, rubber, paper, wood, cloth, and chemical residues
20	Food and kindred products	Processing, packaging, and shipping	Meats, fats, oils, bones, offal vegetables, fruits, nuts and shells, and cereals
22	Textile mill products	Weaving, processing, dyeing, and shipping	Cloth and fiber residues
23	Apparel and other finished products	Cutting, sewing, sizing, and pressing	Cloth and fibers, metals, plastics, and rubber
24	Lumber and wood products	Sawmills, mill work plants, wooden container, misc. wood products, manufacturing	Scrap wood, shavings, sawdust; in some instances metals, plastics, fibers, glues, sealers, paints, and solvents
25	Furniture, wood	Manufacture of household and office furniture, partitions, office and store fixtures, and mattreses	Those listed under Code 24, and in addition cloth and padding residues

---

[a] Source: Standard industrial classification manual, 1967

TABLE 8. SOURCES AND TYPES OF INDUSTRIAL WASTES (cont'd)

Code	S. I. C. Group Classification	Waste generating processes	Expected specific wastes
25	Furniture, metal	Manufacture of household and office furniture, lockers, bedsprings, and frames	Metals, plastics, resins, glass, wood, rubber, adhesives, cloth, and paper
26	Paper and allied products	Paper manufacture, conversion of paper and paperboard, manufacture of paperboard boxes and containers	Paper and fiber residues, chemicals, paper coatings and fillers, inks, glues, and fasteners
27	Printing and publishing	Newspaper publishing, printing, lithography, engraving, and bookbinding	Paper, newsprint, cardboard, metals, chemicals, cloth, inks, and glues
28	Chemicals and related products	Manufacture and preparation of inorganic chemicals (ranges from drugs and soups to paints and varnishes, and explosives)	Organic and inorganic chemicals, metals, plastics, rubber, glass, oils, paints, solvents and pigments
29	Petroleum refining and related industries	Manufacture of paving and roofing materials	Asphalt and tars, felts, asbestos, paper, cloth, and fiber
30	Rubber and miscellaneous plastic products	Manufacture of fabricated rubber and plastic products	Scrap rubber and plastics, lampblack, curing compounds, and dyes
31	Leather and leather products	Leather tanning and finishing; manufacture of leather belting and packing	Scrap leather, thread, dyes, oils, processing and curing compounds

TABLE 8. SOURCES AND TYPES OF INDUSTRIAL WASTES (cont'd)

Code	S. I. C. Group Classification	Waste generating processes	Expected specific wastes
32	Stone, clay, and glass products	Manufacture of flat glass, fabrication or forming of glass; manufacture of concrete, gypsum, and plaster products; forming and processing of stone and stone products, abrasives, asbestos, and misc. nonmineral products	Glass, cement, clay, ceramics, gypsum, asbestos, stone, paper, and abrasives
33	Primary metal industries	Melting, casting, forging, drawing, rolling, forming, and extruding operations	Ferrous and nonferrous metals scrap, slag, sand, cores, patterns, bonding agents
34	Fabricated metal products	Manufacture of metal cans, hand tools, general hardware, nonelectric heating apparatus, plumbing fixtures, fabricated structural products, wire, farm machinery and equipment, coating and engraving of metal	Metals, ceramics, sand, slag, scale, coatings, solvents, lubricants, pickling liquors
35	Machinery (except electrical)	Manufacture of equipment for construction, mining, elevators, moving stairways, conveyors, industrial trucks, trailers, stackers, machine tools, etc.	Slag, sand, cores, metal scrap, wood, plastics, resins, rubber, cloth, paints, solvents, petroleum products

TABLE 8. SOURCES AND TYPES OF INDUSTRIAL WASTES (cont'd)

Code	S. I. C. Group Classification	Waste generating processes	Expected specific wastes
36	Electrical	Manufacture of electric equipment, appliances, and communication apparatus, machining, drawing, forming, welding, stamping, winding, painting, plating, baking, and firing operations	Metal scrap, carbon, glass, exotic metals, rubber, plastics, resins, fibers, cloth residues
37	Transportation Equipment	Manufacture of motor vehicles, truck and bus bodies, motor vehicle parts and accessories, aircraft and parts, ship and boat building and repairing motorcycles and bicycles and parts, etc.	Metal scrap, glass, fiber, wood, rubber, plastics, cloth, paints, solvents, petroleum products
38	Professional, scientific controlling instruments	Manufacture of engineering, laboratory, and research instruments and associated equipment	Metals, plastics, resins, glass, wood, rubber, fibers, and abrasives
39	Miscellaneous manufacturing	Manufacture of jewelry, silverware, plated ware, toys, amusement, sporting and athletic goods, costume novelties, buttons, brooms, brushes, signs, and advertising displays	Metals, glass, plastics, resins, leather, rubber, composition, bone, cloth, straw, adhesives, paints, solvents

TABLE 11

SOLID WASTE GENERATION BY MAJOR FARM ANIMALS (1966)

Animal	Number on Farms (thousands)	Waste load (manure) (tons/unit/yr)	Waste load (manure) (thousand tons/yr)	
Cattle	108, 862	10	1, 088, 620	
Hogs	47, 414	8	379, 312	
Sheep	21, 456	3	64, 368	
Horses, mules	No estimate since 1960	-------	---------	
Poultry				
Broilers	2, 568, 338	. 0045	11, 557	
Turkeys	115, 507	. 025	2, 888	
Layers	339, 921	. 047	15, 976	
Ducks, etc.	No estimate	-------	---------	
TOTAL			1, 562, 721	
			7, 814	tons/cap/yr.
			15, 627. 2	lbs/cap/yr.
			42. 8	lbs/cap/day

TABLE 12. GENERATION BY TYPE OF SOLID WASTES FROM THE MINERAL AND FOSSIL FUEL INDUSTRIES (1965)

Industry	Mine waste	Mill tailings	Washing plant rejects	Slag	Processing Plant wastes	Total (thousands of tons)
Copper	286,600	170,500	---	5,200	---	466,700
Iron and Steel	117,599	100,589	---	14,689	1,000	233,877
Bituminous coal	12,800	---	86,800	---	---	99,600
Phosphate rock	72	---	54,823	4,030	9,383	68,308
Lead-zinc	2,500	17,811	970	---	---	20,311
Aluminum	-----	---	---	---	5,350	5,350
Anthracite coal	-----	---	2,000	---	---	2,000
Coal ash	-----	---	---	---	24,500	24,500
Other [a]	-----	---	---	---	---	229,284
Totals	419,571	288,900	144,593	23,919	40,233	1,146,500

[a] Estimated waste generated by remaining mineral mining and processing industries.

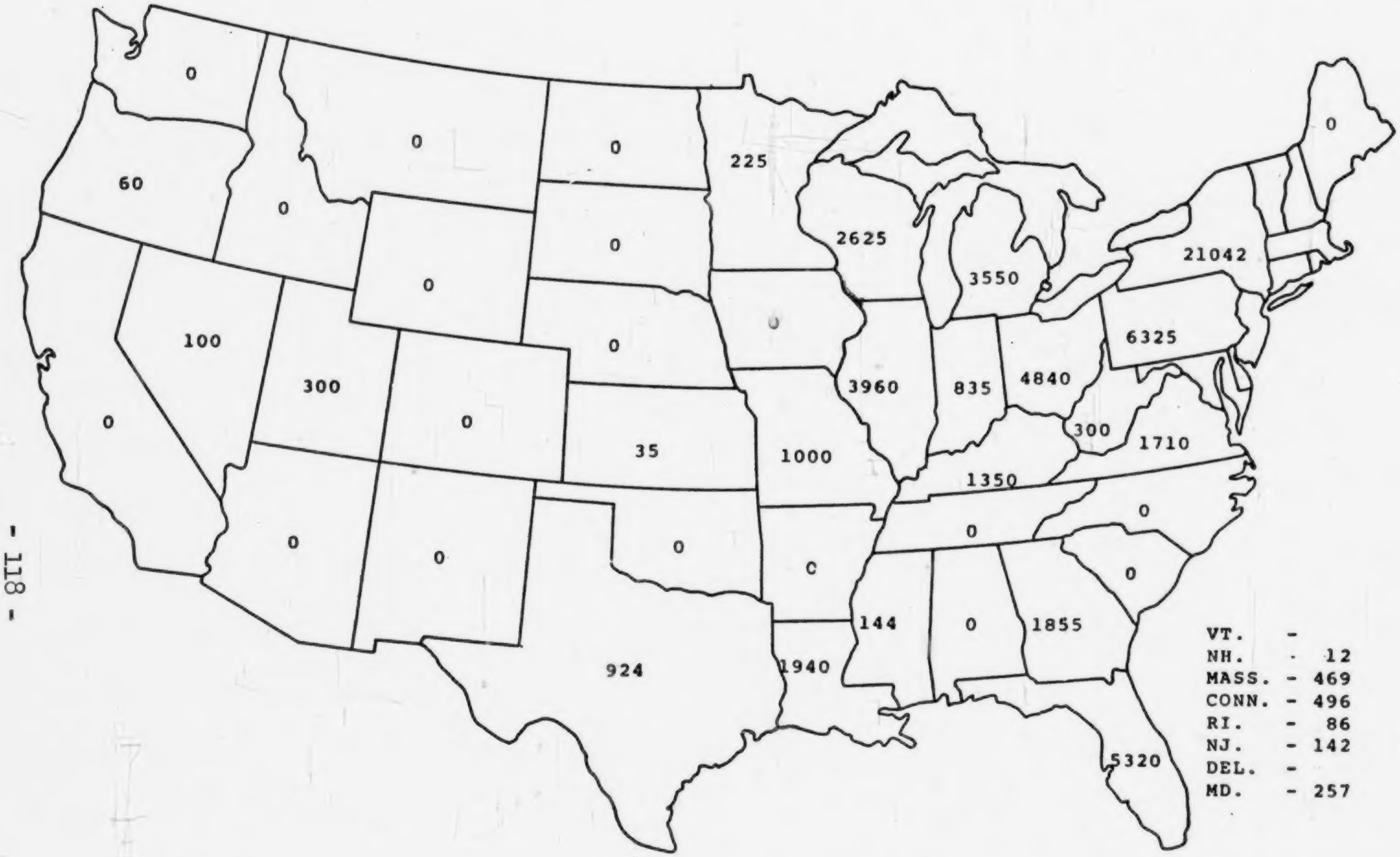

0
60
0
100
300
0
0
0
0
0
0
0
0
35
0
924
225
0
1000
C
1940
2625
3960
3550
835
1350
0
144
0
4840
300
1710
0
0
1855
5320
21042
6325
0
VT. -
NH. - 12
MASS. - 469
CONN. - 496
RI. - 86
NJ. - 142
DEL. -
MD. - 257

FIG. 5. DISTRIBUTION BY STATES OF THE INSTALLED RATED CAPACITY (TONS PER 24-HOUR DAY) OF MUNICIPAL INCINERATORS IN OPERATION IN 1966.

Recently some rail carriers have established a new classification for compost materials. The classification, "waste products," carries a 30 per cent lower freight rate than fertilizer products. There still remains room for improvement since earth or stone can be moved by rail 60 per cent cheaper than fertilizer products. If still lower rates could be provided by rail carriers to compost producers, distribution of compost to a much larger area might become feasible.

Despite municipal interest in the process, technical development of it, considerable investment, and much hope, only 1 of the 15 composting plants built in the United States during the last 17 years has operated for a period long enough to indicate success; 8 have been shut down in failure. Most of the plants that have closed were operated by private businessmen who expected to realize a profit, balancing the cost of processing refuse into compost against a fee charged to the city plus proceeds from the sale of the compost.

The main difficulty in most start-up operations is the unsuitability of many items found in city refuse for hammermill and grinding operations. Another factor is location. Despite claims to the contrary, there is an odor from compost and from compost plants, especially in warm, humid weather. When earlier compost plant operators went into production and began to face the task of marketing compost, their first efforts were directed towards the farmer. The only success in this market that can be reported is in Florida where the compost was sold to citrus and vegetable farmers.

Utilization and Salvage

Diversion of fractions of the overall waste material from a waste stream to the basic and natural resources of the nation is one example of the method called "direct recycling," commonly called "salvage." The term has been used rather loosely in practice to include both residues, such as metal scrap which was recycled within an industry for utilization and hence never really a part of the community waste stream, and materials and objects which are segregated from mixed refuse and sold. In this latter category are such items as rags, bottles, paper, nonferrous metals, and metal cans, which are destined for the landfill unless sorted out and reclaimed. This distinction between "reduction at source" and "direct recycling," is useful for both technological and economic reasons.

In the broader sense, including both reclaiming and recycling, salvage forms the basis of an enterprise estimated to range from $5 to $7 billion annually in the United States. It is, in fact, an essential part of the economy in that were it not for the utilization of scrap materials there would be insufficient raw materials at acceptable prices to meet the need of basic industries. Nevertheless, the management of solid wastes is assuming critical proportions. Therefore, it can only be said that without reclaiming and recycling the problem would be worse.

The ideal system of solid waste management will be one which results in the maximum reduction in wastes for disposal by way of reuse or recycling, and the disposition of the irreducible residue without insult and perhaps even enhancement to the environment. Direct recycling is most readily carried out in situations in which the waste is relatively homogeneous and high in value. These conditions prevail most frequently in commercial and industrial operations. On the other hand, when reusable material is mixed with garbage and other refuse, its reclamation is difficult because economics effectively controls salvage and reclamation practices. As a result, salvage in municipal operations is relatively limited and sporadic. This difficult fraction cannot be ignored, however, because it represents a sizable portion of the nation's wastes (or resources).

Junk Automobiles.

In 1966 it was estimated that about 6 million scrap cars were processed and sold to the steel and other metalworking industries for reuse, nearly equalling the number of cars being junked. This was the first time that the utilization of automobile hulks equalled the scrapping rate. Large, high capital-cost auto shredding plants constructed in the large urban centers have only in recent years processed more automobile hulks from the accumulated backlog of cars in the urban centers than were currently being junked in those areas. At the same time, however, more scrapped automobiles were being added to the accumulation of junked cars, estimated at 10 to 20 million scattered in wrecking yards throughout the United States, particularly in areas where operation of the high-cost shredding plants is economically impractical. This pattern of scrap automobile accumulation threatens to continue. Furthermore, the quality standards for ferrou scrap are changing, so that it is likely that difficulties will develop in the marketing of shredded metal in excess of the rate of accumulation. Specifications for steel have grown more stringent. Residual elements not removed from iron or steel during normal refining processes, particularly copper, nickel, aluminum, chromium, and vanadium, have slowly been accumulating in steel to a point where little or no casual scrap can be tolerated in many uses that formerly consumed substantial quantities of scrap iron.

A number of scrap preparation plants has recently been constructed in which auto body scrap is reduced to a relatively dense, loose product. The processes involve feeding prepared car bodies to large hammermills which break the frames and bodies into small pieces and densify them. A major disadvantage to the shredding plants is that they require a capital investment of several million dollars and only operate economically in densely populated areas where an abundant supply of junked cars is available.

Ash.

Power plant bottom ash finds utilization in cinder block manufacture, as road ballast, and in uses on highways during icy weather. Fly ash sometimes can be used as a soil conditioner and as an additive to concrete and asphalt mixes. These uses, however, consume less than 10 percent of the fly ash generated. Thus, most of this extremely fine-sized material is dumped in spoil areas adjacent to or near the power plants at a cost ranging from 40 cents to $2.00 per ton. Because many power generating plants are located in large urban centers, satisfactory disposal areas for the ash are becoming scarce, and even under the most favorable conditions of disposal, the spoil piles cause air and water pollution from dusting and silting, and deface the landscape as well. The ideal method of disposing of fly ash would be to recycle all of it to industry for reuse as a raw material. The factors that limit or discourage any widespread utilization of the fly ash are: (1) the extreme variability in its chemical and physical properties; (2) cost of transporting the raw fly ash or products manufactured from fly ash to major consumer markets; (3) competition of other raw materials which are readily available to industry.

Rubber.

The reclaimed rubber industry appears to have existed approximately 100 years. The waste rubber industry has two main segments; the scrap dealers, who buy, segregate and resell rubber; and the rubber reclaimers who reprocess scrap rubber so it can be used again. At the reclamation plant, the collected scrap rubber is graded into one of the following categories: (1) whole, modified whole, and nonstaining tires; (2) "peeling" reclaims; (3) synthetic reclaims and butyl tube neoprene; (4) specialties; (5) natural rubber reclaims (red and black). The reclaimed rubber which can be revulcanized is ground, subjected to chemical treatment, and is then processed into rubber sheets for use in the manufacture of new rubber articles.

The economics of rubber salvage, especially of tires, varies according to locale. The Midwest Rubber Company's St. Louis facility pays $14 per ton (f. o. b. processor's yard) for waste rubber. An area having a radius of 600 miles is combed for raw materials to meet the Company's commitments. The price paid in Akron is $12 per ton and in Los Angeles the price is $7.50 per ton. The freight charge for shipping used tires from San Francisco to Los Angeles is $9.50 per ton. Some tire companies are actually paying the $4.00 (split between the freight and the broker's commission) just to get rid of their waste tires. Reclaimed rubber brings $200 to $240 per ton, compared to about $500 per ton for synthetic butyl Grade-1 rubber.

Other Industries.

Some industries achieve very high utilization of scrap-and-waste, these being cotton at 59 percent, mostly by return to the land as soil amendment; wooden boxes at 50 percent, mostly through sale of chips; saw mills at 66 percent by sale of chips and use of bark, slabs and sawdust for fuels; auto and aircraft at 50 percent; stockyards at 60 percent by utilization for fertilizer; supermarkets at 40 percent, mostly by entering the commercial salvage stream; millwork at 47 percent; and printing and publishing (greater than 250 employees) 68 percent. At might be expected, fabricated metal products and machinery, except electrical, show a high fraction utilized, 81 percent for metal cans and 51 percent for the remainder of these two sectors because most of their waste is metal scrap which readily finds utilization in the commercial salvage market. The meat packing industry has found it possible through the years to utilize more and more of the animal as "by-product" and is now listed at 44 percent, but this 44 percent did not actually enter the waste-for-disposal category as defined in this report.

Disposal

Disposal is the ultimate step in a solid waste management system. All solid wastes, whether raw refuse, sewage sludge, incinerator fly ash and residue, and compost, must be utilized in some way or given final disposal. The major categories of disposal are open dumping, open burning, ocean disposal, mulching, land spreading, animal feeding, and sanitary landfilling.

Open dumping has been and is the simplest and most widely used means of disposal of solid wastes. The last decade has seen extensive changes in the method of urban waste disposal. By and large, the most advanced method of ultimate disposal for urban areas is the sanitary landfill. Sanitary landfilling is a method of disposing of refuse on land without creating nuisance or hazard to public health or safety by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary.

Urban Waste Disposal.

The National Survey results illustrate the wide variety of community approaches to the disposal of solid wastes and also give emphasis to the gap between the actual and desirable methodology.

Land disposal sites provide by far the predominant disposal method in use by American communities. The 6300 communities made use of about 8900 land disposal sites and about 1000 other disposal or waste reduction facilities.[1] (Table 14)

In a separate investigation of sites and facilities, in connection with the survey, a total of over 6000 land disposal sites have been visited and surveyed thus far. Some 79% of these landfills were operated by public agencies. Nevertheless only 14% of the sites were adjudged by the interviewers to be sanitary landfills. Moreover the survey form itself permits further evaluation of site standards, and on the basis of a review of the forms it appears likely that less than 6% of them can truly be characterized as "sanitary landfills." Although the sanitary landfill has been recommended by engineers for many years, its acceptance by the public is still far from universal.

While making use of about 10,000 sites and facilities the presence of which was known and accounted for, and for which some form of control could be exercised, the communities acknowledged, at the same time, the presence within community bounds of almost an equal number (9300) of unauthorized or promiscuous dumps over which there was no control whatever and little knowledge as to the offenders. The absence of controls and probably also in great measure the absence of adequate community provision for solid wastes are responsible for such a state of affairs. The failure to exercise modern controls can be seen in community response to questions concerning open burning of wastes within the community. Almost 68% of communities replying to the question indicate burning of demolition-construction wastes and land clearance wastes takes place within the community. Over 69% gave the same response on the burning of commercial wastes on site. In the case of backyard burning of household refuse the figure was over 82%. Even 66% of urban communities, as distinct from rural, countenance backyard burning.

---

[1] These figures undoubtedly include some double counting due to the likelihood that two or more communities use the same site.

The recent trend among larger communities is away from sanitary landfill and toward incineration. Reasons for this include: lack of available landfill sites, long distances required for hauling, and the need to preserve as long as possible the remaining landfill locations. Incineration is not a complete disposal method and considerable sanitary landfilling is needed to dispose of incinerator residue and noncombustible materials.

Disposal of hospital wastes products is generally accomplished by the following three methods: (1) incineration followed by burial or trucking to final disposal site; (2) trucking away to final disposal site; (3) grinding and discharge to sanitary sewer systems. The introduction of many new single-service items and the increasing use of disposable materials has greatly altered the types and quantities of hospital solid wastes. This change is usually noticed by its effect on incinerator loadings and operations. The problems inherent in the safe handling of such items as plastic syringes, rubber gloves, catheters, emesis basins, and plastic petri dishes by such means as outdoor storage and municipal collection, involve special considerations for the safety of hospital staff, waste collectors, and the public at large.

Industrial Waste Disposal.

Burning and dumping are the most widely used methods of disposal for industrial solid wastes. These methods are increasingly unacceptable in the face of more stringent air and water pollution regulations and the

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name:____________________________

Address:____________________________

____

Working Title:______________________

Unit No. & Title:____________________

____

Date Submitted:____________________

Hours Spent on this lesson:________

(Block below for instructor use)

Date Received:______________

Date Returned:______________

Comments:

____

(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 13

PERSISTENT CHEMICALS

Unit No. 13

Persistent Chemicals

Reading:

Wagner, Chapters 12, 13, 14, 17

Odum, pp. 445 - 448

Brubaker, pp. 108-111

Ecological Effects of Pesticides on Non-Target Species

Air Evaluation and Summary by David Pimentel of Cornell University, published by the Office of Science and Technology.

Assignment:

Continue work on your term paper, which will be due with Unit No. 16.

Pollution by Pesticides

Various estimates indicate that as many as 500 thousand different chemical substances may have been released into our environment. We simply do not know what the effects may be for all but a very few of them. The problem is complicated by the fact that some of the substances change, after they are released. Some may become harmless, some may become changed into more harmful chemicals.

A number of chemicals -- including DDT, which has been studied possibly to a greater extent than any other -- a number of these chemicals persist in the soil, or in the air, or in water, for as long as 10 or 15 years. Some are concentrated by various organisms in the food chains that occur naturally. For example, floating micro-organisms may concentrate a chemical that is harmless in low concentrations. In turn, larger organisms -- water insects, and various arthropods -- eat the microscopic plants or animals and concentrate the chemical further. Small fish, then larger fish, then fish-eating birds may, at each link of the food chain, store or concentrate still larger amounts. At the top of the chain, the concentration may be hundreds or even thousands of times greater than it was originally.

The harmful effects must, of course, be balanced against the beneficial effects. DDT for example, has saved millions of lives by destruction of disease carriers, has benefitted perhaps two billion people more especially in saving food supplies, and it has resulted in damage to wildlife, more particularly birds such as the bald eagle, and several falcons, as well as fish and other water-living organisms.

Persistent Chemicals

Our problems with the environment are made all the more difficult by the way we have been putting persistent chemicals into it. If the chemicals disappeared in a short time, the problems with them might not be great. But many of the chemicals we use and that escape into the environment or that we simply dump into it, last a long, long time. They are often very complex substances, and many are not always broken down into simpler compounds by bacteria or fungi, at least, not very soon. Thus, many waste products and other substances we use for a variety of purposes, linger for months or years in the soil or water.

To understand what this means, we may classify the chemicals we have been putting into our environment in this way:

1. Pesticides

   These are chemicals we use to destroy insect pests (insecticides), or weeds (herbicides), or fungi (fungicides), or rats and mice and other rodents (rodenticides). In total we call these pesticides, meaning something that kills pests. Most of these are agricultural chemicals, although not all of them are.

2. Radioactive materials

These are chemicals that are radioactive. This means that they are giving off destructive rays, -- beta rays and gamma rays. Almost all of these come from the testing of atomic bombs. Radioactive strontium, iodine, and other substances, fall out of the atmosphere and contaminate the soil or water. They continue radiating for months, or for many years, depending on the substance.

3. Chemical Waste products

Here we classify a wide variety of chemicals that are simply dumped into our rivers or oceans, or that escape into the atmosphere and eventually are washed down into the soil and rivers by rain. There are upwards of several hundred thousand kinds of such material. We know very little about most of them, in relation to the environment. A few, such as PCB's (short for polychlorinated biphenyls), mercury compounds, and a few others, last a long time -- decades perhaps -- before they are broken down into simpler, harmless substances, or rendered harmless in some other way. Some of them -- such as mercury -- never can be eliminated.

All three types of compounds -- pesticides, radioactive materials, and chemical waste products -- are new products. They are new to the environment, new to the decay organisms, with unexpected or unknown effects. Most of them were put into soil or water or the atmosphere in the more or less indifferent belief that it would make no particular difference.

We were intent on something else. The pesticides were aimed at insects or fungus diseases of crop plants, or rodents. The waste products were something simply to dispose of by washing down the drain. Radioactive fallout was a by-product of nuclear tests. We learned later on that some of them could and did do a lot of damage in the environment. We had not expected this. Apparently, it simply did not occur to most of us that such chemicals might have effects in air environment that we did not intend.

Some very strange things happened to many of these products. Some of them spread into the environment in exceedingly minute quantities. But, present in parts per billion, or parts per million, they were taken up by bacteria or other organisms that happened to be immune to their direct effects, and concentrated. Various organisms absorbed them -- and accumulated them in their bodies. When these organisms were eaten by larger organisms in the food chain, the larger organisms accumulated more of the chemical -- and so on, up the food chain.

At the top of the food chain, the amounts present were amounts far beyond the original concentrations in the water, or soil, or air. Thus, we humans, at the top or near the top of the food chain, were getting hundreds or thousands of times as much of the chemicals as were present in the environment. These amounts could very possibly cause us some damage. The worst of it was that this concentration of chemicals was something we did not realize was happening. In fact, we didn't expect it to. Nobody did.

The things that can happen can be illustrated by a brief account of DDT. This substance has been more studied than most other pesticides. It is a spray most people have heard about. It is used to kill many kinds of insect pests on crop plants, on buildings, in swamps, and on body lice on people. Some experts think it is one of the best insecticides we have ever had. It is perfectly safe to handle, humans are not poisoned by it as far as we know. It is highly effective against many pests. And it lasts a long time and thus keeps on killing pests long after it is applied. These things we knew early in its history.

And so, in 1946, this excellent insecticide was introduced into commercial use. After a time we began to learn more about it. What we learned would have been pretty difficult to find out ahead of time. Factors that appeared later were these:

1. DDT would persist in the soil for as much as 15 years or more.

2. It was discovered in oceanic birds, and in the seals and penguins of the antarctic, great distances away from any place it was being used. At first, no one knew how it reached them.

3. We found out that it volatilized, that is, it got into the air as a vapor, from soil or water. This meant that it could be carried about in the atmosphere by winds, all around the world.

4. It was concentrated in natural food chains. It might be present in extremely minute quantities in the air or water, but organisms stored it up, one after another up the food chain. Sometimes it was concentrated as much as 100,000 times, meaning that animals at the top of a food chain might contain 100,000 times as much of it in their bodies as there was in the soil or water or air.

5. DDT is now present in animal life and human beings almost everywhere. We have it in our body fats, the Eskimos have it. We began to be uneasy, then alarmed, about this. What effects would it have on us, and on other organisms?

6. So far at least, it hasn't hurt human beings. The American Medical Association stated in 1970 that it certainly does not cause cancer. Other effects on people? None are known so far.

7. It has seriously hurt some types of wildlife. With some birds including eagles, ducks, certain quails, hawks, pelicans, --it causes the eggshells to be very thin. They are so thin they break before the young birds inside are ready. This prevents the birds from raising young, and gradually the number of birds decreases.

8. Birds such as robins and sparrows died after feeding, on earthworms that had concentrated DDT or one of its breakdown products known as DDE. Many other kinds of birds were affected in one way or another. The effects were slight with some birds. With others, the population declined, either from eggshell thinning, interference with breeding, or death.

9. Many kinds of fish died after DDT got in the water, but other species were not affected. This depended on the concentration of DDT, and on other factors. Some kinds of frogs died; other kinds didn't. Many kinds of insects were not affected. But a great many kinds died, some of them the very ones that preyed on the pest insect.

10. In very minute concentrations, such as 1 part per billion, populations of phytoplankton -- the microscopic floating plants in fresh or salt water -- were reduced by half or more. In

some studies, photosynethesis was found to be reduced substantially in certain algae of the oceans. The present concentration in the oceans is said to be in the parts per trillion range.

11. DDT works itself out of a job, so to speak. When it is used to kill flies, for example, it kills almost the whole population of flies where it is used -- all but a very few. These few flies are somehow resistant to it. They breed up a whole new population of flies resistant to DDT. On this new breed, we have to use some other chemical.

12. All these effects are now affected by another one discovered only recently. It turns out that many of the identifications of DDT by highly sensitive and accurate instruments have been identifying as DDT has really been something else. Some chemicals known as PCB's or polychlorinated biphenyls give closely similar readings on our instruments. These chemicals are used in the manufacture of paints and plastics. They last a long time in the environment too, and furthermore they damage wildlife in much the same way that DDT does.

13. Where DDT has been banned from use, poisonings increase among people who use other and frequently far more dangerous chemicals. In one country in Central America, upwards of a thousand people died this way within about a year after DDT was banned. Having used "safe" DDT, they were careless in handling chemicals very poisonous to human beings.

14. Extreme difficulty in raising some crops -- such as cotton -- is expected if DDT cannot be used because we do not have satisfactory alternatives at the present time. Several million people depend on cotton for a living in this country. Some of the chemicals used instead of DDT on cotton, kill honeybees that pollinate the plants. Very large losses to the beekeepers, and to the people raising crops dependent on bees for pollination are on record where these substitutes have been used.

15. Other methods of insect control are being developed that may ultimately enable us to get along without DDT, at least in the present form. We underscore ultimately, however, because the scientists say we are still quite a long way away from being able to depend entirely on these new methods.

For many of the chemical substances we have released, the amounts getting into the environment were relatively small and local. They appear not to have had significant ecological effects on the world as a whole. Even these statements must be accepted with reservation however; we are simply not sure.

But with chemicals used to spray hundreds of thousands of acres of soil or water, the story is different. Nearly a billion pounds of registered insecticides were applied in the United States during 1970. This is an enormous quantity, and not all of it was persistent in the environment.

In the decade 1960 - 1969, more than 2.5 billion pounds of the most persistent chemicals used as pesticides were produced in the United States. DDT accounted for nearly 1½ billion pounds. The rest was made up of the group listed below.

The persistence for a number of the pesticides is now known. It is expressed as the half-life. This means that a pesticide with a half-life of, say, 8 years, will be half gone in 8 years. Half of the remaining half disappears in the next eight years, and half of the remainder takes another 8 years to disappear. Thus, in 24 years, half is gone in 8 years, a quarter more is gone in 16 years, and an eighth more is gone in 24. This still leaves 1/8 of the original still on hand. The half-life of some of the more persistent, organic pesticides is:

aldrin	9 years	heptachlor	2-4 years
chlordane	6 years	lindane	2 years
DDT	15 years	toxophene	11 years
dieldrin	7 years		
endrin	14 years		

With this variety of factors, (and there may be more yet to come) it is not a matter for surprise that the scientists have had a quite a time dealing with this problem. The vast complex of inter-relationships between this particular chemical, and the thousands of kinds of soil organisms, the cycles pursued by carbon, nitrogen, oxygen, hydrogen, water, and other substances or elements, the chemical reactions in the atmosphere, the photosynthetic activities of green plants, the millions of interactions among plants and animals -- all these involve an almost fantastic maze of relationships not only beyond the scientists, but beyond any computer or combination of computers so far devised.

We need to keep in mind that DDT is just one chemical among thousands, that the persistent chemicals as a group is only one of a large number of environmental problems, that all these problems must be solved in relationship to each other, and that upon the solution to these problems a great deal may depend insofar as our sojourn on this planet is concerned.

Ecological Effects of Pesticides
On Non-Target Species
by David Pimentel
Executive Office of the President
Office of Science and Technology
June 1971

PART VI

An Evaluation and Summary

Of the nearly 1 billion pounds of pesticides applied in the United States during 1970, about 51 percent was for farm use, and the remaining 49 percent for public and governmental use. This amounts to about 5 lbs of pesticide applied per person for pest control. The bulk of the pesticides was aimed at about 2,000 pest species; these species make up only about 1 percent of the total 200,000 species of plants and animals in the United States. As expected, many of the non-target species were directly or indirectly affected by the pesticides used.

In the encyclopedic review of the ecological effects of pesticides on non-target species, there is wide variation in the amount of information available concerning the effects of a particular pesticide. DDT, for example, when compared with other pesticides, has been well investigated, as have some others in the chlorinated insecticide group. Even so, the available data on the impact of these pesticides involve fewer than 1,000 species of the estimated total of 200,000 species. The abundance or scarcity of information on a particular pesticide should not be interpreted as an indication of either a hazard or the absence of one. In general, a quick scan of the data reveals that the greatest amount of information is available on insecticides and the least amount on fungicides and their effects on non-target species. Information concerning effects of herbicides is intermediate, yet nearly as much herbicide material is applied as insecticides.

Modes of Action of Pesticides

Little is known concerning the mode of action of most pesticides for either pest or non-target species. The available evidence documents the fact that the mode of action of each pesticide varies significantly with individual species. For example, DDE (a metabolite of DDT) is practically nontoxic to insects, but predaceous bird species like the American sparrow hawk are highly sensitive to it. This chemical affects the predaceous birds' reproductive physiology and causes the birds to produce eggs with eggshells from 10 to 30 percent thinner than normal. Interestingly enough, seed-eating birds like quail and pheasants are relatively resistant to the effects of DDE.

Reducing Species Numbers

The direct application of pesticides to crop lands, forests, and other habitats may reduce and sometimes temporarily exterminate not only the pest, but also non-target species in the treated area. This, of course, is not surprising because a pesticide is an active poison applied specifically to destroy animals and plants designated as pests.

While the direct effects of pesticides are relatively easily observed, the indirect effects are far more complicated to detect. For example, it is difficult to discern whether the numbers of a species are declining and if they are, whether the decline is because of a pesticide or because of the numerous other environmental factors which impinge upon natural populations. In investigating the indirect effects of pesticides it may be difficult to determine how the pesticide was transported in the environment, how the non-target species were exposed, and what dosage of pesticide they received.

An example of the problems involved in determining the impact of pesticides on non-target species was the investigation of why some predaceous bird species declined in habitats where chlorinated insecticide residues were abundant. Some wildlife biologists suspected DDT residues were having an adverse effect, but the influence of urbanization was recognized as an additional factor contributing to bird mortality. When studying natural populations, it is nearly impossible to single out each factor and gauge just how it contributes to the total mortality.

Proof that DDT was responsible for the observed decline of some predaceous birds required the exposure of some of these birds to known amounts of pesticides under controlled conditions. To do this the investigators first had to rear birds of prey (in this case the American sparrow hawk) in the laboratory and then feed them measured amounts of DDT and dieldrin at dosages similar to those occurring naturally. Feeding a combination of DDT and dieldrin in the diet of the sparrow hawk caused the birds to produce eggs with significantly thinner eggshells, and the loss of eggs was significantly increased above untreated controls.

Another example of measuring the impact of a pesticide indirectly on a non-target species involved the decline of lake trout in Lake George and other nearby lakes. For several years previous to the observed decline in the lake trout population, about 10,000 pounds of DDT had been applied yearly for pest control in the watershed surrounding Lake George. Some DDT found its way into the lake, but the amount was believed to be small. Although DDT residues were found in both adult lake trout (8 to 835 ppm of DDT in fat) and their eggs (3 to 355 ppm of DDT), the mature lake trout appeared unaffected, and their eggs hatched normally. The reason for the decline remained a mystery until it was discovered that the young fry were highly sensitive to certain levels of the DDT in the eggs. Thus fry were killed at the time of final absorption of the yolk and just when the young were ready to feed. With 3 ppm of DDT in the eggs a few fry survived, but at 5 ppm or higher mortality was 100 percent. The reason the lake trout population was declining in the lakes was then obvious.

Predaceous and parasitic insect populations have been reduced and even eliminated in some regions after insecticide usage, and this sometimes resulted in outbreaks of particular insect and mite species which had been previously kept under control by these species. For example, when predaceous coccinellid beetle populations were inadvertently eliminated in areas treated with DDT, chlordane, and other chemicals, outbreaks of mites, aphids, and scale insects occurred. At times the densities of these plant pests increased 20-fold above their "natural control" level.

Habitat Alteration and Species Reductions

Man using plow and bulldozer has significantly altered many natural habitats and caused significant reductions in some species of plants and animals, but pesticides have been equally effective in altering habitats. Dimethoate applied to a red clover field, for example, reduced the number of insects on which mice were feeding, and this reduced the numbers of mice present. DDT and other insecticides which find their way into streams significantly reduce invertebrate populations. Subsequently, salmon and other fish populations which depend upon these invertebrates may also be reduced.

Herbicide destruction of plants on which animals depend for food may also cause significant reductions in their numbers For example, 2,4-D applied to a gopher habitat reduced the forbs by 83 percent, and eventually this resulted in an 87-percent reduction in the dependent gopher population.

Changes in vegetation are usually detrimental to dependent species, but the change may also be favorable for other species. For instance, when the tops of mature forest trees were killed with herbicides, the trees sprouted from their bases, thus improving the browse for white-tailed deer.

Behavioral Changes

Pesticides have been found to alter the normal behavior of several animal species. For example, sublethal dosages of dieldrin fed to sheep increased the number of trials required by the animals to relearn a visual discrimination test. Also, sublethal doses of DDT caused trout to lose most of their learned avoidance response.

Salmon, when exposed to sublethal doses of DDT, were found to prefer water of higher temperatures than usual. If this type of exposure occurred in nature, the salmon might place their eggs in regions where their fry could not survive. Mosquito fish exposed to low concentrations of DDT (0.1 to 20 ppb) tended to prefer waters with a higher level of salinity than normal for the species.

The herbicide 2,4-D caused predaceous coccinellid beetles to be sluggish, and this change would alter their predatory activities and effectiveness as a biological control agent.

Growth of Animals and Plants

The biological activity of pesticides suppressed growth in some species and stimulated growth in others. Female white-tailed deer, for example, when fed 5 ppm and 25 ppm of dieldrin daily in their diet for 3 years grew much more slowly than untreated females.

2,4-D was reported to increase the time for growth and development of predaceous coccinellid beetle larvae by nearly 60 percent. This could significantly reduce the effectiveness of these animals in biological control of aphids and other pest insects. On the other hand, 2,4-D stimulated the growth of the rice stemborer pest. Caterpillars of the borer grew 45 percent larger on the treated plants than on the untreated rice plants.

Plant growth may also be affected, as when corn and beans were grown in soil treated with DDT at 10 ppm and 100 ppm. At the end of 4 weeks the corn weighed nearly 40 percent more than corn in the untreated soil. Beans, however, weighed significantly less (30 percent) after 8 weeks when exposed to DDT concentration of 10 ppm than beans grown in untreated soil.

Reproduction

Pesticides caused measurable changes in the reproduction of various non-target animals. White-tailed deer females fed 25 ppm of dieldrin in their food, for example, had lower fawn survival than untreated does.

Pesticides appear to have a deleterious effect on the reproduction of some predaceous birds such as the American sparrow hawk, already mentioned. In some natural habitats the brown pelican has been exposed to DDT and DDE, and it is reported that egg breakage has resulted recently in a complete reproductive failure. Generally, aquatic fish-eating birds have been more severely affected than terrestrial-bird predators because they obtain more DDT, DDE, and other pesticide residues in their food.

Unfortunately, the effects of pesticides on reproduction in birds are more varied than just eggshell thinning. For example, ovulation time in finches reportedly doubled when the birds were fed DDT in their diet, thus increasing the time required for a generation. Also, embryo mortality during egg incubation ranged from 30 to 50 percent when mallard ducks had been fed 40 ppm of DDE in their diet. Total duckling production was reduced by as much as 75 percent when the ducks received this level of DDE.

DDT, DDE, and dieldrin were not the only chemicals to affect reproduction in birds. Both 2,4-D and 2,4,5-T at relatively high dosages depressed reproduction in chickens, as did 2,4-D and silvex in mallard ducks and toxaphene in bobwhite quail and pheasants, and thiram-exposed chickens produced abnormally-shaped and soft-shelled eggs.

Female mosquito fish reproduction was affected because they aborted their young after surviving exposure to sublethal dosages of DDT, TDE, methoxychlor, aldrin, endrin, toxaphene, heptachlor, and lindane.

Pesticides may also increase the rate of reproduction. For example, the exposure of bean plants to 2,4-D increased aphid progeny production during a 10-day period from 139 to 764 per aphid mother.

Food Quality Changes

The chemical makeup of plants may be altered by pesticides, and this in turn affects the dependent animals. The changes which do occur appear to be quite specific for both plants and pesticides. Several chlorinated insecticides both increased some elements and decreased others in corn and beans. For example, heptachlor in soil at dosages of 1, 10, and 100 ppm caused significant changes in the macro and micro elements (N, P, K, Ca, Mg, Mn, Fe, Cu, B, Al, Sr, and Zn) measured in the aboveground portions of corn and bean plants. Zinc was significantly higher (89 ppm, dry weight) in bean plants treated with 100 ppm of heptachlor than in untreated controls (55 ppm); however, nitrogen levels were significantly lower (4.99 percent) in the treated plants than in the untreated controls (7.25 percent). Investigators reported an increased protein content in wheat exposed to 2,4-D in contrast with beans grown on 2,4-D-treated soil, which reduced protein content in the beans.

The potassium nitrate content of sugar beet plants exposed to a sublethal dosage of 2,4-D increased from a normal of 0.22 percent to 4.5 percent (dry weight), a nitrate level highly toxic to cattle. 2,4-D and other herbicides have also been reported as increasing the nitrate content of various other plants.

Another change in the chemical content of plants after exposure to pesticides is an increase in sugars. Ragwort, a weed naturally toxic to many animals including cattle, when exposed to sublethal doses of 2,4-D, has a high level of sugar. The increased sugar content in the weed makes it attractive to cattle and sheep, with disastrous results because the toxic level of the plant remains high as the sugar content increases. In Sudan grass 2,4,5-T increased the hydrocyanic acid content by 69 percent, a level in some cases toxic to animals.

Pesticide Resistance in Animals and Plants

The evolutionary impact of pesticides on animals and plants is evidenced by the number of species which have evolved high levels of tolerance to various pesticides. For example, a house mouse population selected for resistance to DDT increased its tolerance to DDT 2-fold in just 10 generations. A pine-mouse population studied in the field was reported to have a 12-fold level of tolerance to endrin above usual levels.

Mosquito fish populations inhabiting streams in the cotton belt evolved significant levels of resistance to DDT, strobane, toxaphene, chlordane, aldrin, heptachlor, dieldrin, endrin, and dursban. Extremely high increases in level of tolerance were reported for strobane (300-fold), endrin (120-fold), toxaphene (40-fold), dieldrin (20-fold), and chlordane (20-fold).

Two frog populations from a cotton-growing region possessed a significant level of resistance to DDT.

As might be expected, insect and mite populations with high levels of resistance to pesticides have been found in many parts of the world. Of nearly 2,000 pest insect and mite species, a total of 225 species has been reported resistant to pesticides. Of these species, 121 species were crop pests, 97 man and animal pests, 6 stored-product pests, and 1 forest pest. In at least one instance the level of resistance had increased 25,000-fold.

Although the evidence is not conclusive, there is strong suggestion of the presence of resistance to 2,4-D in some plants.

Disease Susceptibility

Pesticides caused animals to be more susceptible to certain diseases. For instance, the exposure of mallard ducklings to Arochlor (PCB) increased the susceptibility of the ducklings to duck hepatitus virus. Also, evidence suggests that the exposure of fish to carbaryl and 2,4-D reduced their natural resistance to a microsporidian parasite.

Biological Concentration

The ability of animals and plants to concentrate many types of pesticides in their body tissues appears to be a common physiological phenomenon. The chlorinated insecticides have the greatest affinity for this type of process. The tremendous capacity for concentrating pesticides is best illustrated with oysters and waterfleas. Oysters were able to take DDT at 1 ppb in seawater and concentrate it 70,000 times in their bodies. Waterfleas were even more efficient; they were able to take DDT at 0.5 ppb in water and concentrate it 100,000 times in their bodies.

Normally, the capacity for biological concentration is not as great as this, but when the event is repeated through several links in the food chain, extremely high concentrations of pesticide residues can occur in the species at the top of the food chain.

This happened with the food chain involving soil, earthworms, and robins. Starting with a DDT level in the soil of 9.9 ppm, it reached 141 ppm in the earthworms and 444 ppm in robins. This high concentration in the robins was toxic to some birds.

Persistence

Persistent pesticides have the advantage of remaining in the environment for long periods and thereby being effective in pest control over long periods of time with fewer applications needed.

The obvious disadvantage is that the longer the chemical poisons persist, the greater are the chances that they will move out of the treated area via either soil, water, air, or organisms and cause harm to non-target organisms.

Of the insecticides, arsenic at reported use dosages remained in the environment for an estimated 40 years. The chlorinated insecticides also persist for long periods ranging from 6 months to 30 years, depending on the chemical, its dosage, and characteristics of the environment. DDT, for example, at only 1 lb/A persisted in a forest environment for 9 years with little decline in the residue level. Based on the rate of disappearance, the estimation was that DDT even at this low dosage would endure for 30 years. Yet for other economic poisons like malathion, residues may persist for only a few days.

It should be pointed out that even with persistent chlorinated insecticides certain limited amounts can be released into the environment without important ecological effects. This level of release, if known, would help develop rational use programs for pesticides.

Pesticide Movement and Residues in the Environment

The presence of pesticides is generally widespread in the environment, and movement throughout the environment is related in large measure to their persistence. Obviously, the longer a chemical remains in the environment, the greater is the opportunity that it will spread or be transported to another location in the environment.

Antarctic seals and penguins far distant from the application of any pesticides are contaminated with DDT. Also, in the Arctic region seals, caribou, and polar bears contain DDT. A great variety of non-target mammals, birds, fishes, and insects are known to contain residues of numerous kinds of pesticides including the highly toxic mercury compounds. Accumulations of pesticide residues in some resistant non-target species have become sufficiently high to be lethal to some individuals of the species itself and to some predators which feed on them.

Residues of pesticides in soil have been investigated extensively, and persistence in soil was discussed above.

Various pesticide residues are found at low levels in water throughout the United States; however, in the southeast and far west, pesticide residues were present at fairly high levels.

A surprising finding was that pesticides also were detected at fairly high levels in the atmosphere. Insecticide levels in areas far distant from any treated area ranged from below detectable levels to 23 ng/m^3 of DDT, for example. Evidently, movement through the atmosphere provides an excellent means for transport of some pesticides to widely dispersed habitats.

The amount of pesticide released into the atmosphere above the crop, but which does not reach the treated crop, is well illustrated with aircraft spraying. For example, in treating corn by aircraft only about 26 percent of the DDT sprayed from aircraft reached the corn when measured at tassel height.

Pesticides accumulated in living organisms may also travel long distances; the impact of this means of pesticides moving out through the environment probably has been underestimated.

Herbicides are generally less persistent than insecticides, but there are materials like picloram and monuron which will persist for 2 to 3 years in the soil. Fungicides also break down rather rapidly, but some like mercury compounds may leave various stable forms free to move in the biosphere for many years.

Wildlife Management

Although, as documented, pesticides can harm wildlife, with careful use they may also benefit wildlife and therefore be employed in some phases of wildlife management.

Insecticides, for example, are sometimes applied to prevent a serious insect pest from denuding a forest of its leaves and making it an unsuitable habitat for some wildlife species. Herbicides have been employed to alter directly the vegetational types growing in a habitat to improve the habitat for food and shelter for deer, grouse, turkey, and quail.

Herbicides have also been used to control water hyacinth and other aquatic weeds, thereby improving the freshwater habitat for sport fish. The quantity of herbicide used for this purpose alone totals several tons per year.

Conclusions

Available evidence suggests that current methods of pesticide use are a serious hazard to some species which make up our environmental life system. Pesticides, especially the chlorinated insecticides (DDT, dieldrin, toxaphene, chlordane, TDE, aldrin, and heptachlor) already have caused measurable damage to non-target bird, fish, and beneficial insect populations. The prime reason for these chemicals being particularly hazardous is their persistence, movement through the ecosystem, and characteristics for biological concentration in the food chain.

Data on the detrimental effects of other pesticides is spotty, but there is sufficient evidence for concern. More information on the impact these economic poisons are having on non-target species is needed before additional plant and animal species are affected.

Based on available information, some generalizations can be made about the effects of insecticides, herbicides, and fungicides on populations and communities of natural species:

1. Pesticides tend to reduce significantly the numbers of individuals of some species in biotic communities, which has the similar ecological effect of reducing the number of species.
2. An important reduction in the number of species in a community may lead to instability within that community and subsequently to population outbreaks because of alteration in the normal check-balance structure of the community.
3. After pesticide applications the species populations most likely to increase in numbers are those in the lower part of the food chain, that is, the plant feeders. This is, in part, because the parasitic and predaceous enemies which naturally help control numbers of plant feeders often are more susceptible to pesticide pollution effects.
4. In addition, any effective loss of species or intense fluctuations in number of species low in the food chain may adversely affect the dependent predator and parasitic species at the top of the food chain. This in turn further disrupts the structure and ultimately the stability of the natural community.

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name:_________________________ _______

Address:_____________________________

____

Working Title:________________________

Unit No. & Title:______________________

____

Date Submitted:_______________________

Hours Spent on this lesson:__________

(Block below for instructor use)

Date Received:_________________

Date Returned:_________________

Comments:

____

(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 14

RADIOACTIVITY

Unit No. 14

Radioactivity

Reading:

A.E.C. leaflets: Atoms, Nature, and Man

Nuclear Power and the Environment

Wagner, Chapter 11

Odum, Chapter 17

Brubaker, pp. 96-105

Assignment:

Continue work on your term paper.

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name: ______________________________

Address: ____________________________

____

Working Title: ______________________

Unit No. & Title: ___________________

____

Date Submitted: _____________________

Hours Spent on this lesson: _________

(Block below for instructor use)

Date Received: _______________

Date Returned: _______________

Comments:

____

(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 15

LIVING SPACE AND RECREATION

Unit No. 15

Living Space and Recreation

Reading:

Wagner, Chapters 19, 20

Brubaker, pp. 188-192

Not required, but additional reading might well include Planned Urban Environments by Ann Louise Strong, Johns Hopkins Press, Baltimore, 1971. 406 pp. Get it at your library or from the USDA Library, Washington, D. C.

Assignment:

1. Continue your term paper which should now be nearing completion.

2. Review your clipping collection. You will be expected to turn in a selected sample of these clippings with the next, and last Unit No. 16. The sample will be *your* selection and should be the best you have been able to collect on any subject you chose.

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name:____________________________

Address:____________________________

____

Working Title:________________________

Unit No. & Title:____________________

____

Date Submitted:______________________

Hours Spent on this lesson:________

(Block below for instructor use)

Date Received:________________

Date Returned:________________

Comments:

____

(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

UNIT NO. 16

LAW AND THE ENVIRONMENT

Unit No. 16

Law and the Environment

Reading:

Recent Progress (attached)

National Environmental Policy Act of 1969

Brubaker, pp. 162-196, 222-233

Assignment:

1. Turn in your finished term paper.
2. Turn in a selected sample of your clippings, together with a statement on the volume and kind of clippings not sent in.

In our capital, we have a new agency -- The Council on Environmental Quality. This was set up in accordance with the National Environmental Policy Act, signed into law by the President of the United States on January 1, 1970. The President called this Council "The keeper of our environmental conscience" and noted that "it will have the responsibility for ensuring that all our programs and actions are undertaken for the needs of environmental quality . . . ." I only wish there were time here to read the whole National Environmental Policy Act aloud; it is a heart-warming, simply-written, very broad, and beautifully-formulated piece of legislation, and it is only a few pages long. Many state governments are already following suit, setting up similar councils for state activities.

A series of executive orders and directives have spelled out the various means we will use to make the national policy effective in every activity of government. This applies not only to specific projects -- such as watershed protection projects, for example -- but also it applies to all new legislation and to all appropriation items. For each, there must be placed on file and made public, a statement explaining its impact on the environment, setting forth both good and bad effects, any irreversible effects, and any alternatives to the proposal. Well over a thousand such statements had been filed by late 1971, involving familiar projects, such as the Alaska pipeline, the Water Bank Act, nuclear power plants, ocean dumping of chemicals, nuclear tests, the Florida jet port, some beach erosion projects, a number of Army Engineer flood control projects, the Oklawaha canal, a series of highway proposals (including state as well as federal, since both are using federal funds), large number of small watershed projects, and so on.

This most environmentalists agree, is an excellent first step in the right direction. There is no approval or disapproval by the Council, although it has commented on a few -- and agencies have paid close attention. Predictions are that we may need some kind of evaluation that has force behind it. After all, there are some projects proposed that perhaps should not be carried out at all.

The Council is to do another very important job. It is to prepare an annual Environmental Quality Report to be sent to Congress each July 1. The first such report was issued in August of 1970. These reports are to set forth the conditions of our environment, major trends, problems, actions underway, and opportunities for the future.

Perhaps, as we observe such important developments as these, involving as they do very basic reforms in the process of government no less than the development of completely new national policies, perhaps we can now see how we may be able to deal more decisively and effectively with a great many ecological problems.

Whether or not the considerable public excitement over the very serious condition of our environment is maintained or not, the effect has been sufficiently profound to cause a major redirection of our government. The new policies and new procedures are rapidly permeating every level. We have much of the knowledge we need and now we have the beginnings of a mechanism to get that knowledge into action. The big problem, of course, is to get enough people involved to get the programs going.

By this time it will no doubt have occurred to you that all of us may be in need of some further education so that we can understand both the problems and the scientific approach to them.

At this point we could look about us for someone to blame. We could blame industry for its polluting effects, or farmers for their misuse of land, or the manufacturers for exhaust emissions from cars. Or, we could blame the scientists for not keeping us better informed through clear, simple writings about ecology. Or, we could blame our schools, primary and secondary, and especially the universities for not giving all of us an adequate grounding in science.

But no matter how hard we seek to assess blame, in the end the fault is really yours and mine.

We live in a world which we cannot understand fully without understanding at least the basic concepts in biology, chemistry, and physics. We do not have to be expert in many scientific fields, nor indeed expert in any particular one. But we do need to be able to follow what the scientists tell us, to be able to evaluate intelligently the findings they are coming up with, and to develop objective judgments about environmental problems.

Unless we -- all of us -- have this understanding, we can scarcely expect to play a proper part in our government, to vote on environmental issues, or to be intelligently active in community, state, national, or international affairs.

What this means, of course, is that all of us need to learn about our environment very early in our education. In grammar school and high school we need to develop an increasingly better understanding of the world in which we live. By the time we complete college, we ought to be well enough equipped with the necessary knowledge -- the factual knowledge -- so that we can deal in a really enlightened and intelligent way with the environmental issues that may confront us.

And, if the educational system should fail us, we have other means. We can undertake our own education! There are, as we have already noted some very good TV programs that may help us in our self-education. There are books by the score -- many of them inexpensive paperbacks -- that we can read and study. There are conferences and sessions where we can listen and discuss. As we do this, let us remember that we need to develop a scientific attitude about our readings, about TV programs, and indeed, about our courses in school or college.

The scientific attitude is simply this: question everything and everybody, look for the truth, discard all but the truth.

The opportunities confront us in unlimited number. As we go forward to take advantage of them, let us do so with enthusiasm but at the same time let us remain coolly aware of what the ecologists are trying to tell us, namely: progress in improving our environment in the long run leads to a better life, but progress at the expense of the environment in the long run leads to catastrophe.

Public Law 91-190
91st Congress, S. 1075
January 1, 1970

An Act

83 STAT. 852

To establish a national policy for the environment, to provide for the establishment of a Council on Environmental Quality, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Environmental Policy Act of 1969".

National Environmental Policy Act of 1969.

PURPOSE

Sec. 2. The purposes of this Act are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality.

TITLE I

DECLARATION OF NATIONAL ENVIRONMENTAL POLICY

Policies and goals.

Sec. 101. (a) The Congress, recognizing the profound impact of man's activity on the interrelations of all components of the natural environment, particularly the profound influences of population growth, high-density urbanization, industrial expansion, resource exploitation, and new and expanding technological advances and recognizing further the critical importance of restoring and maintaining environmental quality to the overall welfare and development of man, declares that it is the continuing policy of the Federal Government, in cooperation with State and local governments, and other concerned public and private organizations, to use all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans.

(b) In order to carry out the policy set forth in this Act, it is the continuing responsibility of the Federal Government to use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate Federal plans, functions, programs, and resources to the end that the Nation may—

(1) fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;

(2) assure for all Americans safe, healthful, productive, and esthetically and culturally pleasing surroundings;

(3) attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences;

(4) preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment which supports diversity and variety of individual choice;

(5) achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities; and

(6) enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources.

(c) The Congress recognizes that each person should enjoy a healthful environment and that each person has a responsibility to contribute to the preservation and enhancement of the environment.

Administration.

SEC. 102. The Congress authorizes and directs that, to the fullest extent possible: (1) the policies, regulations, and public laws of the United States shall be interpreted and administered in accordance with the policies set forth in this Act, and (2) all agencies of the Federal Government shall—

(A) utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decisionmaking which may have an impact on man's environment;

(B) identify and develop methods and procedures, in consultation with the Council on Environmental Quality established by title II of this Act, which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations;

(C) include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on—

(i) the environmental impact of the proposed action,

(ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,

(iii) alternatives to the proposed action,

(iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

(v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Copies of statements, etc.; availability.

81 Stat. 54.

Prior to making any detailed statement, the responsible Federal official shall consult with and obtain the comments of any Federal agency which has jurisdiction by law or special expertise with respect to any environmental impact involved. Copies of such statement and the comments and views of the appropriate Federal, State, and local agencies, which are authorized to develop and enforce environmental standards, shall be made available to the President, the Council on Environmental Quality and to the public as provided by section 552 of title 5, United States Code, and shall accompany the proposal through the existing agency review processes;

(D) study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources;

(E) recognize the worldwide and long-range character of environmental problems and, where consistent with the foreign policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind's world environment;

(F) make available to States, counties, municipalities, institutions, and individuals, advice and information useful in restoring, maintaining, and enhancing the quality of the environment;

(G) initiate and utilize ecological information in the planning and development of resource-oriented projects; and

(H) assist the Council on Environmental Quality established by title II of this Act.

Review.

Sec. 103. All agencies of the Federal Government shall review their present statutory authority, administrative regulations, and current policies and procedures for the purpose of determining whether there are any deficiencies or inconsistencies therein which prohibit full compliance with the purposes and provisions of this Act and shall propose to the President not later than July 1, 1971, such measures as may be necessary to bring their authority and policies into conformity with the intent, purposes, and procedures set forth in this Act.

Sec. 104. Nothing in Section 102 or 103 shall in any way affect the specific statutory obligations of any Federal agency (1) to comply with criteria or standards of environmental quality, (2) to coordinate or consult with any other Federal or State agency, or (3) to act, or refrain from acting contingent upon the recommendations or certification of any other Federal or State agency.

Sec. 105. The policies and goals set forth in this Act are supplementary to those set forth in existing authorizations of Federal agencies.

TITLE II

COUNCIL ON ENVIRONMENTAL QUALITY

Report to Congress.

Sec. 201. The President shall transmit to the Congress annually beginning July 1, 1970, an Environmental Quality Report (hereinafter referred to as the "report") which shall set forth (1) the status and condition of the major natural, manmade, or altered environmental classes of the Nation, including, but not limited to, the air, the aquatic, including marine, estuarine, and fresh water, and the terrestrial environment, including, but not limited to, the forest, dryland, wetland, range, urban, suburban, and rural environment; (2) current and foreseeable trends in the quality, management and utilization of such environments and the effects of those trends on the social, economic, and other requirements of the Nation; (3) the adequacy of available natural resources for fulfilling human and economic requirements of the Nation in the light of expected population pressures; (4) a review of the programs and activities (including regulatory activities) of the Federal Government, the State and local governments, and nongovernmental entities or individuals, with particular reference to their effect on the environment and on the conservation, development and utilization of natural resources; and (5) a program for remedying the deficiencies of existing programs and activities, together with recommendations for legislation.

Council on Environmental Quality.

Sec. 202. There is created in the Executive Office of the President a Council on Environmental Quality (hereinafter referred to as the "Council"). The Council shall be composed of three members who shall be appointed by the President to serve at his pleasure, by and with the advice and consent of the Senate. The President shall designate one of the members of the Council to serve as Chairman. Each member shall be a person who, as a result of his training, experience, and attainments, is exceptionally well qualified to analyze and interpret environmental trends and information of all kinds; to appraise programs and activities of the Federal Government in the light of the policy set forth in title I of this Act; to be conscious of and responsive to the scientific, economic, social, esthetic, and cultural needs and interests of the Nation; and to formulate and recommend national policies to promote the improvement of the quality of the environment.

SEC. 203. The Council may employ such officers and employees as may be necessary to carry out its functions under this Act. In addition, the Council may employ and fix the compensation of such experts and consultants as may be necessary for the carrying out of its functions under this Act, in accordance with section 3109 of title 5, United States Code (but without regard to the last sentence thereof). 80 Stat. 416.

Duties and functions.

SEC. 204. It shall be the duty and function of the Council—

(1) to assist and advise the President in the preparation of the Environmental Quality Report required by section 201;

(2) to gather timely and authoritative information concerning the conditions and trends in the quality of the environment both current and prospective, to analyze and interpret such information for the purpose of determining whether such conditions and trends are interfering, or are likely to interfere, with the achievement of the policy set forth in title I of this Act, and to compile and submit to the President studies relating to such conditions and trends;

(3) to review and appraise the various programs and activities of the Federal Government in the light of the policy set forth in title I of this Act for the purpose of determining the extent to which such programs and activities are contributing to the achievement of such policy, and to make recommendations to the President with respect thereto;

(4) to develop and recommend to the President national policies to foster and promote the improvement of environmental quality to meet the conservation, social, economic, health, and other requirements and goals of the Nation;

(5) to conduct investigations, studies, surveys, research, and analyses relating to ecological systems and environmental quality;

(6) to document and define changes in the natural environment, including the plant and animal systems, and to accumulate necessary data and other information for a continuing analysis of these changes or trends and an interpretation of their underlying causes;

(7) to report at least once each year to the President on the state and condition of the environment; and

(8) to make and furnish such studies, reports thereon, and recommendations with respect to matters of policy and legislation as the President may request.

SEC. 205. In exercising its powers, functions, and duties under this Act, the Council shall—

(1) consult with the Citizens' Advisory Committee on Environmental Quality established by Executive Order numbered 11472, dated May 29, 1969, and with such representatives of science, industry, agriculture, labor, conservation organizations, State and local governments and other groups, as it deems advisable; and 34 F. R. 8693.

(2) utilize, to the fullest extent possible, the services, facilities, and information (including statistical information) of public and private agencies and organizations, and individuals, in order that duplication of effort and expense may be avoided, thus assuring that the Council's activities will not unnecessarily overlap or conflict with similar activities authorized by law and performed by established agencies.

SEC. 206. Members of the Council shall serve full time and the Chairman of the Council shall be compensated at the rate provided for Level II of the Executive Schedule Pay Rates (5 U.S.C. 5313). The other members of the Council shall be compensated at the rate provided for Level IV or the Executive Schedule Pay Rates (5 U.S.C. 5315).

Tenure and compensation.
80 Stat. 460, 461.
81 Stat. 638.

SEC. 207. There are authorized to be appropriated to carry out the provisions of this Act not to exceed $300,000 for fiscal year 1970, $700,000 for fiscal year 1971, and $1,000,000 for each fiscal year thereafter.

Appropriations.

Approved January 1, 1970.

LEGISLATIVE HISTORY:

HOUSE REPORTS: No. 91-378, 91-378, pt. 2, accompanying H. R. 12549 (Comm. on Merchant Marine & Fisheries) and 91-765 (Comm. of Conference).
SENATE REPORT No. 91-296 (Comm. on Interior & Insular Affairs).
CONGRESSIONAL RECORD, Vol. 115 (1969):
July 10: Considered and passed Senate.
Sept.23: Considered and passed House, amended, in lieu of H. R. 12549.
Oct. 8: Senate disagreed to House amendments; agreed to conference.
Dec. 20: Senate agreed to conference report.
Dec. 22: House agreed to conference report.

HOME STUDY COURSE RESPONSE SHEET

The American Environment

Name: ______________________________

Address: ____________________________

____

Working Title: ______________________

Unit No. & Title: ___________________

____

Date Submitted: _____________________

Hours Spent on this lesson: ________

(Block below for instructor use)

Date Received: ______________

Date Returned: ______________

Comments:

____

(Instructor's Signature

Begin lesson assignment below. Use additional sheets as needed.

(If lesson assignment is required, please transmit this response sheet to your instructor along with the assignment.)

☆ U. S. GOVERNMENT PRINTING OFFICE : 1973—513-971/1255